DRAFT FOR STATE AND FEDERAL REVIEW

Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site RI/FS

Feasibility Study Report - Phase I

Allied Paper, Inc./Portage Creek/
Kalamazoo River Superfund Site
Kalamazoo and Allegan Counties,
Michigan

October 2000

BBL
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Disclaimer

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Acronyms and Abbreviations

ABSA	aquatic biota sampling area
AChE	acetylclolinesterase
AEM	Applied Environmental Management
Allied OU	Allied Paper, Inc. Operable Unit
AOC	Administrative Order by Consent
ARARs	applicable or relevant and appropriate requirements
ARCS	Assessment and Remediation of Contaminated Sediments
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BAF	Bioaccumulation factor
BBEPC	Blasland & Bouck Engineers, P.C.
BBL	Blasland, Bouck & Lee, Inc.
^{7}Be	Beryllium^{7}
bgs	below ground surface
BSAF	biota sediment accumulation factor
BSP	Biota Sampling Plan
°C	degrees Celsius
C	PCB concentration in the mixed layer
C_1	PCB concentration on depositing sediment
CAD	Confined aquatic disposal
CDM	Camp Dresser & McKee, Inc.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
CLIS	Central Long Island Sound Disposal Site
CLP	Contract Laboratory Program
cm	Centimeter
^{137}Cs	Cesium^{137}
CTF	Confined Treatment Facility
CV	coefficient of variation
CWA	Clean Water Act
cy	cubic yards
DCB	decachlorobiphenyl
DCS	Description of the Current Situation
DMP	Data Management Plan
DO	dissolved oxygen
DOC	dissolved organic carbon
DOE	Department of Energy
EFF	engine fuel factor
EE/CA	Engineering Evaluation/Cost Analysis
EFCM	East Foundry Cove Marsh
EIR/RAP	Environmental Impact Report/Remedial Action Plan
EM	Engineer Manual
EPCs	exposure point concentrations
ERA	Ecological Risk Assessment
ETWG	Engineering/Technology Work Group
°F	degrees Fahrenheit

FERC	Federal Energy Regulatory Agency
FFS	Focused Feasibility Study
FINDS	Facilities Index Data System
FM	frequency modulation
FML	flexible membrane liner
FOIA	Freedom of Information Act
fps	feet per second
FRRAT	Fox River Remediation Advisory Team
FS	Feasibility Study
FSP	Field Sampling Plan
GE	General Electric Company
Georgia-Pacific	Georgia-Pacific Corporation
Giesy	Giesy Ecotoxicology, Inc.
GLEAS	Great Lakes Environmental Assessment Section
GLNPO	Great Lakes National Program Office
GLSFATF	Great Lakes States Fish Advisory Task Force
gpd/sf	gallons per day per square foot
GPR	ground penetrating radar
GPS	global positioning system
GRA	General Response Action
GSI	Groundwater/Surface Water Interface
HARS	Historic Area Remediation Site
HASP	Health and Safety Plan
HDPE	high density polyethylene
HHRA	Human Health Risk Assessment
HP	horsepower
HPV	health protective value
HRDL	Historic Residuals Dewatering Lagoon
HSI	habitat suitability index
HQ	hazard quotient
IEPA	Illinois Environmental Protection Agency
IJC	International Joint Commission
IRM	interim response measure
JSA	Arcadis JSA
K	fish condition factor
KALSIM	Kalamazoo River PCB Simulation Model
kg	kilogram
kg/yr	kilogram per year
KHL-OU	King Highway Landfill Operable Unit
kHz	kilohertz
K_{ow}	octanol-water partition coefficient
KRSG	Kalamazoo River Study Group
KRWC	Kalamazoo River Watershed Council
KSSS	King Street storm sewer
KWRP	Kalamazoo Water Reclamation Plant
LMMBS	Lake Michigan Mass Balance Study
LSU	Louisiana State University
LTI	Limno-Tech, Inc.
M&E	Metcalf & Eddy
MDCH	Michigan Department of Community Health

MDEQ	Michigan Department of Environmental Quality
MDL	method detection limit
MDNR	Michigan Department of Natural Resources
MDPH	Michigan Department of Public Health
Metro	Municipality of Metropolitan Seattle
MGD	million gallons per day
mg/kg	milligram per kilogram
mg/L	milligram per liter
MHI	Millennium Holdings, Inc.
MHz	megahertz
mi^2	square miles
m^3	cubic meters
MIOSHA	Michigan Occupational Safety and Health Act
MIRIS	Michigan Resource Information System
mL	milliliter
MNFI	Michigan Natural Features Inventory
Monsanto	Monsanto Industrial Chemicals Company
MS	matrix spike
m/s	meter per second
MSD	matrix spike duplicate
MSL	mean sea level
MSU	Michigan State University
MWRC	Michigan Water Resources Commission
NAAQS	National Ambient Air Quality Standards
NCDC	National Climatic Data Center
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
ng/kg	nanogram per kilogram
ng/L	nanogram per liter
NGVD	National Geodetic Vertical Datum
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NPW	net present worth
NRC	National Research Council
NRD	natural resource damage
NREPA	Natural Resources and Environmental Protection Act
NWI	National Wetlands Inventory
NYSDEC	New York State Department of Environmental Conservation
ODEQ	Oregon Department of Environmental Quality
OME	Ontario Ministry of the Environment
OSHA	Occupational Safety and Health Act
OSI	Ocean Surveys Inc.
OU	Operable Unit
p	statistical significance level
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl(s)
PCDD/PCDF	polychlorinated dibenzodioxins and dibenzofurans
POC	particulate organic carbon
POLREP	Pollution Report
POTW	publicly owned treatment works
ppb	part per billion

ppm	parts per million
PRP	potentially responsible party
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
r^2	coefficient of determination
RCRA	Resource Conservation and Recovery Act
RD/RA	remedial design/remedial action
residuals	paper-making residuals
RI	Remedial Investigation
RI Report	Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site Remedial Investigation Report
ROD	Record of Decision
RPD	relative percent difference
RRO	remedial response objective
S	deposition rate
SARA	Superfund Amendments and Reauthorization Act
SDG	sample delivery group
SIC	Standard Industrial Classification
Site	Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site
SMU	Sediment Management Unit
SOP	standard operating procedure
SOW	Statement of Work
STL	Severn Trent Laboratories
SVOCs	semivolatile organic compounds
SWAC	surface area weighted average concentration
SWQD	Surface Water Quality Division
t	student's t statistic
TBC	To Be Considered
TBSA	terrestrial biota sampling area
TCDD	tetrachlorinated dibenzo-p-dioxins
TCE	trichloroethene
TCL/TAL	Target Compound List/Target Analyte List
TCMX	tetrachloro-meta-xylene
TEF	toxicity equivalency factor
TOC	total organic carbon
TRI	Toxic Release Inventory
TSCA	Toxic Substances Control Act
TSD	treatment/storage/disposal
TSS	total suspended solids
UCSB	University of California at Santa Barbara
UM	University of Michigan
USACE	United States Army Corps of Engineers
USCS	United Soil Classification System
USDA-SCS	United States Department of Agriculture Soil Conservation Service
USDOT	United States Department of Transportation
USEPA	United States Environmental Protection Agency
USFDA	United States Food and Drug Administration
USFHA	United States Federal Highway Administration
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

VOCs	volatile organic compounds
W	Shapiro – Francia Test Statistic
WB/A-OU	Willow Boulevard/A-Site Operable Unit
WES	Waterways Experiment Station
WET	Wetland Evaluation Technique
WDNR	Wisconsin Department of Natural Resources
WMU	Western Michigan University
WTF	water treatment facility
w/w	wet weight
Z_m	thickness of the mixed layer
µg/kg/day	micrograms per kilogram per day
µg/L	microgram per liter
µg/m^3	microgram per cubic meter

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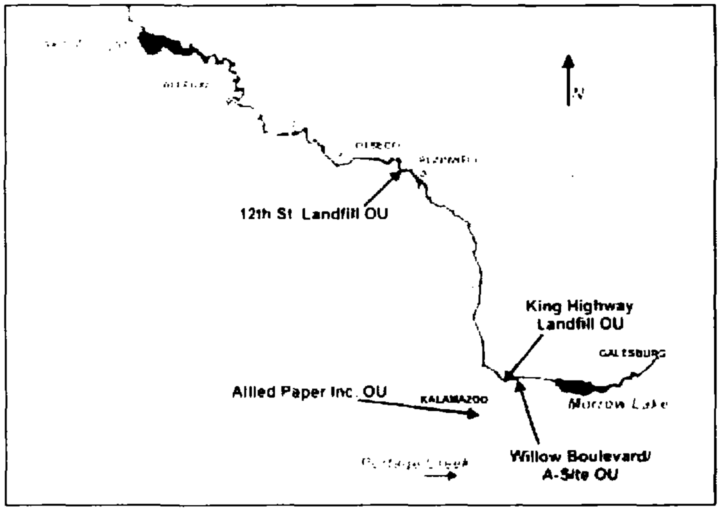

The Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site

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A **Feasibility Study** is primarily an engineering evaluation of the available options to reduce risks at the Site. This study:

- Develops remedial response objectives and general response actions for the Site
- Identifies potential remedial alternatives
- Evaluates and compares alternatives
- Recommends a remedy for the Site

What are pathways?

There are two kinds of pathways relevant to this Site. **Exposure pathways** are the routes through which humans, plants, and animals could come in contact with or ingest PCB to a degree that could pose health risks. **Transport pathways** are mechanisms by which PCB can enter the river and move downstream or be made available for human or ecological exposure.

What part of the river is involved?

Although the area studied includes the Kalamazoo River from Morrow Lake to Lake Michigan, the remedy proposed in this report will focus on the river from Morrow Dam to Lake Allegan Dam (the upper river) and three miles of Portage Creek. The lower river – Lake Allegan Dam to Lake Michigan – will be addressed in a separate report when additional studies are completed.

☛ ***The extensive information gathered during the Remedial Investigation will be used in this Feasibility Study to develop a remedy that will reduce risks.***

1. Introduction

1.1 Purpose and Objectives

> ➢ The findings of the Remedial Investigation (RI) indicate that polychlorinated biphenyls (PCB) are the constituent of concern at the Site. Both the ecological and human health risks posed by PCB result from their accumulation in fish. The goal of this FS process is to develop and evaluate potential remedial alternatives to reduce risk, and recommend a preferred remedy.

This Feasibility Study (FS) Report presents potential remedial alternatives for the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site (Site), located in Kalamazoo and Allegan counties, Michigan. Blasland, Bouck & Lee, Inc. (BBL) has prepared this FS Report on behalf of the Kalamazoo River Study Group (KRSG), which is composed of Millennium Holdings, Inc. (MHI), Georgia-Pacific Corporation (Georgia-Pacific), Fort James Corporation, and Plainwell, Inc. This FS Report represents Phase I of a two-part process addressing activities at the Site between Morrow Dam and Lake Allegan Dam. A Phase II Remedial Investigation/Feasibility Study (RI/FS) that will address the Kalamazoo River from Lake Allegan Dam downstream to Lake Michigan is being prepared separately.

The FS was conducted pursuant to an Administrative Order by Consent (AOC) (Final Order No. DFO-ERD-91-001) issued by the Michigan Department of Natural Resources[1] (MDNR, 1991). The purpose of this FS Report is to identify and evaluate potential remedial alternatives for the Site, and then present a recommended remedial approach for addressing potential threats to public health, welfare, or the environment caused by the release or threatened release of constituents of interest from the Site. (Potential Site risks are identified in the *Phase I Remedial Investigation Report* [RI Report] [BBL, 2000b] and the human health and ecological risk assessments [HHRA and ERA] [Camp Dresser & McKee, Inc. (CDM), 1999a; 2000a; 2000b]). Sections 1 through 3 of this FS Report are also provided as an alternatives array document pursuant to Task 11B of the AOC.

The objectives of this FS Report are to:

- Identify Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered (TBC) information relevant to remedial action at the Site;
- Develop Remedial Response Objectives (RROs) and identify General Response Actions (GRAs);
- Determine Site areas subject to remediation;

[1] The AOC requires that the FS be performed in accordance with Michigan Act 307 (superseded in June 1995 by the Michigan NREPA Part 201) and consistent with CERCLA and the NCP.

- Identify potential remedial technologies and assemble those technologies into potential remedial alternatives for the Site;
- Conduct screening-level and detailed evaluations of the identified potential remedial alternatives;
- Conduct a comparative analysis of the potential remedial alternatives; and
- Recommend remedies for the areas determined to be subject to remediation.

This FS Report has been prepared in accordance with the AOC and is consistent with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR Part 300, Subpart E), the Michigan Natural Resources and Environmental Protection Act (NREPA; Act 451, Part 201), and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1996. In addition, the FS was completed in accordance with the *Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site-Remedial Investigation/Feasibility Study Work Plan* (RI/FS Work Plan) (Blasland & Bouck Engineers, P.C. [BBEPC], 1993c) and addenda (Brown, 1995a; 1995b; 1996; BBL, 1997).

1.2 RI Findings

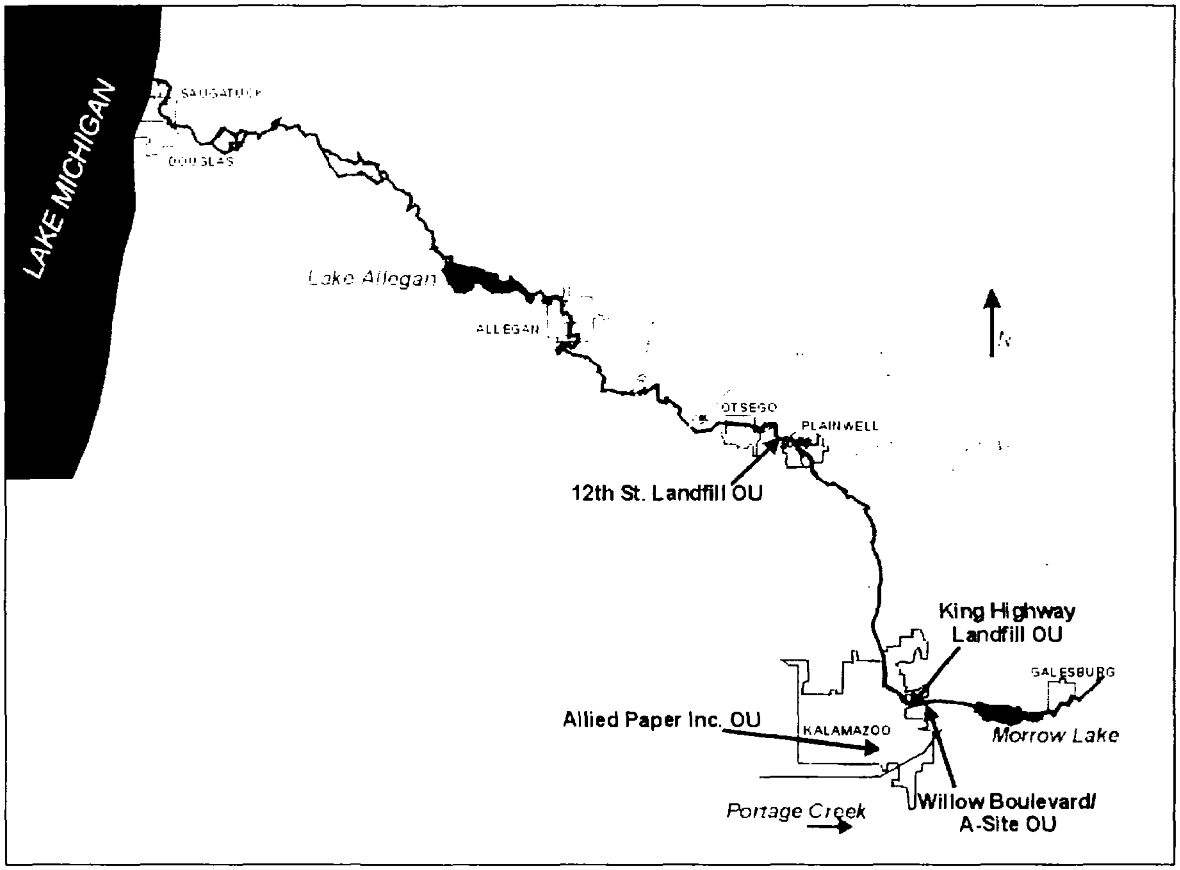
The findings of the RI conducted pursuant to the AOC are summarized in Section 7 of the accompanying RI Report. (BBL, 2000b).

1.3 Geographic Scope of the FS -- Site Background and Description

The total area investigated for this RI/FS (the Site)[2] encompasses the Kalamazoo River from Morrow Lake to Lake Michigan, and Portage Creek from Alcott Street to the Kalamazoo River (see Figure 1-1 and map below). This FS Report addresses activities at the Site between Morrow Dam and Lake Allegan Dam. A separate RI/FS will address the Kalamazoo River from Lake Allegan Dam downstream to Lake Michigan.

The Kalamazoo River and Portage Creek are located in southwestern Michigan (Figure 1-1). The main stem of the Kalamazoo River begins in Albion, Michigan at the confluence of the North and South Branches, and flows in a northwesterly direction for 123 miles through Kalamazoo and Allegan counties before draining into Lake Michigan near the city of Saugatuck. The Kalamazoo River drains an area of approximately 2,000 square miles and is fed by more than 400 miles of tributaries.

[2] The area investigated extends beyond the boundaries of the site, as listed on the National Priority List (NPL). The NPL site is 35 miles of the Kalamazoo River from Portage Creek to the Allegan City Dam and the lower three miles of Portage Creek.



From Morrow Dam to the mouth of the river at Saugatuck, the Kalamazoo River is an alternating series of free-flowing sections and impoundments formed by low-level dams. From upstream to downstream, the dams are Morrow Dam, former Plainwell Dam, Otsego City Dam (also known as the Menasha Dam), former Otsego Dam, former Trowbridge Dam, Allegan City Dam (also known as the Imperial Carving Dam), and Lake Allegan Dam (also known as the Calkins Bridge Dam). The former Plainwell, Otsego, and Trowbridge dams, which are owned by the MDNR, were permanently opened by the MDNR and the impoundments were drawn down to their sill levels in the early 1970s; however, they still impound some water and sediment. The Lake Allegan Dam is owned by Consumers Energy and is still used to generate electric power. The river is still impounded by the Otsego City and Allegan City dams; however, they no longer generate power. Among the 12 tributaries that flow into the river, the largest is the Rabbit River, which discharges to the Kalamazoo River near the Village of New Richmond. Swan Creek, another relatively large tributary, enters the Kalamazoo River at the Swan Creek Marsh, within the Allegan State Game Area. Both of these tributaries enter the Kalamazoo River downstream of Lake Allegan.

To better describe and understand the data collected in the RI/FS efforts, the Kalamazoo River has been divided into reaches based generally on physical characteristics. These reaches are (BBEPC, 1993c):

- Ceresco to Battle Creek (upstream reference site);
- Morrow Lake (upstream reference site);
- Morrow Dam to Portage Creek confluence (Reach A1);
- Portage Creek confluence to Main Street, Plainwell (Reach A2);
- Main Street, Plainwell to the Plainwell Dam (Reach B);
- Plainwell Dam to the Otsego City Dam (Reach C);
- Otsego City Dam to the Otsego Dam (Reach D);
- Otsego Dam to the Trowbridge Dam (Reach E);
- Trowbridge Dam to the Allegan City Line (Reach F);
- Allegan City Line to the Allegan City Dam (Reach G);
- Allegan City Dam to the Lake Allegan Dam (Reach H);
- Lake Allegan Dam to Lake Michigan (Reach I);

Portage Creek, from Alcott Street to its confluence with the Kalamazoo River (Reach P), is also within the scope of the RI/FS.

Characteristics of each reach are briefly described in Section 1.4 of the RI Report (BBL, 2000b).

1.3.1 Operation and Maintenance of Dams

> ➢ Laws and regulations require that dams be maintained and operated so that their operation does not result in release of PCB trapped within the sediment upstream of those dams.

This FS assumes that all dams and impoundments along the river are and will continue to be operated and maintained in compliance with applicable laws and regulations (including State laws that regulate dam safety and maintenance, and prohibit the exacerbation of existing environmental contamination), or will be brought into compliance with the law by the owners of those dams. As discussed in the RI Report (BBL, 2000b), the operation and maintenance of dams has determined, to a significant extent, the current distribution and bioavailability of PCB in the bed of the Kalamazoo River. Estimates of the quantity of PCB in the current river sediment bed show that Morrow Lake (9.6%), the Allegan City Impoundment (8.7%), and Lake Allegan (70%) comprise approximately 88% of the total PCB mass upstream of the Lake Allegan Dam.

It is also assumed that the lands owned by the MDNR upstream of the Plainwell, Otsego, and Trowbridge dams will be maintained for wildlife management and recreational uses. The nature of these lands, which are to a large extent wetlands (including wetlands recognized by the National Wetland Inventory [NWI]), is expected to restrict development of these lands for reasons other than the presence of PCB.

1.4 Pathways to be Addressed by Potential Remedial Alternatives

> - **Consumption of fish from the Kalamazoo River is the only significant exposure pathway for humans and wildlife.**
> - **The predominant external supplier of PCB to the river is erosion of the banks of the MDNR-owned former impoundments.**
> - **Surface sediments are the major in-river supplier of PCB to fish.**

Based on the findings of the RI and both the HHRA and ERA, consumption of fish is the only significant PCB exposure pathway for both humans and ecological receptors such as mink and bald eagles. Other potential exposure pathways were considered, evaluated, and determined to pose no significant risk to human or ecological receptors. For humans, these non-significant pathways include direct contact with or incidental ingestion of sediments, surface water, or floodplain soils. For ecological receptors the terrestrial pathway of PCB transfer from soil to plants and invertebrates and on to higher organisms was considered, but data currently are insufficient to conclude that the transfer of PCB from exposed sediment to the terrestrial community results in significant ecological risk.

The ERA for the site (CDM, 1999a) suggests that based upon screening-level calculations, bald eagles and mink may be at risk through consumption of fish from the Kalamazoo River. Ongoing risk assessment work by Giesy Ecotoxicology, Inc. (Giesy, 2000) will further investigate exposure and risks to these receptors. These results are not currently available. Consequently, risks to these ecological receptors related to the pathway of PCB accumulation in fish will be assumed for the purposes of this assessment, but these hypothetical risk estimates may be reduced or eliminated in the future, based upon actual site-specific factors.

While fish PCB levels control the level of human health and ecological risk at the Site, fish PCB levels are controlled, in turn, by the availability of PCB in surface sediments and the water column. Therefore, mechanisms by which PCB become bioavailable must be considered. The primary transport pathways of PCB to Kalamazoo River surface waters are from loading from external sources and releases from the sediment bed. The primary transport pathways of PCB to the surface bioavailable sediment zone are transport from upstream and external loading. The sloughing and erosion of the exposed former sediments along river banks of the three MDNR-owned former impoundments is the major external source of PCB to the river. The large surface areas of the former impoundments are not a transport pathway because erosion from those areas is limited by the low relief and dense vegetation of the areas. During flooding, these may be areas for net deposition of sediment and PCB from the river. Considering these potential exposure and transport pathways, the effectiveness of any remedy for the Kalamazoo River must be measured against its ability to control the bioavailability of PCB and, in turn, reduce PCB levels in fish.

1.5 Summary of Previous Response Actions

> ➢ Five mills, the King Street storm sewer, and four OUs have been or are being remediated on schedules independent of the plans for the river as a whole.

As part of the Kalamazoo River RI, six properties along the river and Portage Creek were investigated to assess both the potential for PCB to be released to the river and the presence of PCB in areas where paper-making residuals (residuals) had been stored for disposal. The investigation is discussed in detail in the Michigan Department of Environmental Quality (MDEQ)-approved *Technical Memorandum* 15 (BBL, 1996). The six properties are:

- Former Allied Paper, Inc. Bryant Mill property;
- Former King Mill property;
- Georgia-Pacific Kalamazoo Mill and property;
- Plainwell, Inc. Mill and property;
- The King Street storm sewer (KSSS); and
- Former Allied Paper Company Monarch Mill.

Initial investigations at each property revealed that no response was necessary either at the Bryant Mill or the Monarch Mill. The voluntary response activities carried out under MDEQ oversight at the other four properties are briefly described in Section 4 of the RI Report (BBL, 2000b).

Four separate areas adjacent to the Kalamazoo River or Portage Creek were designated as Operable Units (OUs). These areas had been used as disposal sites for residuals and were considered to be potential continuing sources of PCB to the river and creek. The OUs were established to allow RI/FS and other response activities at, and remediation of, these four areas to proceed on an accelerated schedule separate from the remediation plans for the rest of the river and creek. The OUs are:

- Allied Paper, Inc. OU (Allied OU), including former Bryant Mill Pond;
- King Highway Landfill OU (KHL-OU);
- Willow Boulevard/A-Site OU (WB/A-OU); and
- 12th Street Landfill OU.

The activities at each OU are briefly described in Section 4 of the RI Report and in more detail in the specific RI/FS documents prepared for each OU. RI/FS documents have been approved by the MDEQ for the KHL-OU and the 12th Street Landfill OU; a draft RI/Focused Feasibility Study (FFS) for the WB/A-OU has been submitted to the MDEQ for review; and the RI/FS for the Allied OU is in progress.

1.6 Report Organization

The organization of this FS Report follows the U.S. Environmental Protection Agency's (USEPA's) *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final* (USEPA, 1988). For ease of review, this FS Report is organized into the following sections:

- Section 1 provides a description of the FS objectives, presents a brief description of the current condition of the Site, and discusses previous response actions conducted to date;
- Section 2 presents the findings of the Site-specific baseline HHRA (CDM, 2000b) and ERA (CDM, 1999a; 2000a), and identifies RROs and GRAs;
- Section 3 identifies potentially applicable remedial technologies and assembles them into potential remedial alternatives;
- Section 4 provides a detailed evaluation of potential remedial alternatives assembled in Section 3;
- Section 5 provides a comparative analysis of the potential remedial alternatives;
- Section 6 presents the recommended alternative.

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Reducing PCB levels in fish tissue is the primary goal of all response activities at the Site.

The **primary remedial response objective (RRO)** for the Site, based on results of the RI, human health and ecological risk assessments, USEPA guidance, and relevant experience is to: *Reduce PCB concentrations in Kalamazoo River fish to acceptable levels in terms of human health and ecological risk.*

Since there are **no hot spots** in the Kalamazoo River, the entire Site must be considered when evaluating remedial alternatives. Surface sediments and the riverbanks in the three former impoundments contribute bioavailable PCB that could be taken up by fish; therefore, these areas will be considered carefully when developing a remedy.

What are ARARs?

ARARs are applicable or relevant and appropriate requirements of state and federal environmental laws that must be considered when developing remedial actions. There are three broad categories: chemical-specific, action-specific, and location-specific.

What are GRAs?

General response actions, such as natural attenuation, capping, or dredging, are actions that could be used to achieve the remedial response objectives; they are identified based upon review and consideration of ARARs and remedial actions considered or used at similar sites. Twelve GRAs were identified for this Site; most are applicable to exposed or submerged sediment that would be managed to reduce PCB levels in fish.

See Sections 3, 4, & 5 for development & evaluation of the remedial alternatives.

2. Development of Remedial Response Objectives and General Response Actions

As a basis for the development of RROs and identifying GRAs in this section, a baseline HHRA (CDM, 2000b) and ERA (CDM, 1999a; 2000a) were conducted to evaluate potential threats to human health and the environment related to the Site. The preliminary findings of those evaluations are summarized below.

2.1 Summary of Baseline Human Health and Ecological Risk Assessments

> ➢ Human health and ecological risk assessments are discussed in greater detail in Section 6 of the RI Report (BBL, 2000b).

The HHRA (CDM, 2000b) and ERA (CDM, 1999a, 2000a) identify PCB accumulation in fish and the resulting impact on human and ecological receptors as the pathway associated with potentially significant risks at the Site. Those assessments and other related Site studies are summarized at greater length in Section 6 of the accompanying RI report. According to CDM's HHRA, there may be risks to sport anglers and subsistence anglers who consume Kalamazoo River fish (CDM, 2000a). The various PCB levels in fish fillets that were estimated by CDM to be protective of subsistence anglers and sport anglers with varying patterns of fish consumption relative to potential cancer risks and non-cancer risks range from 0.008 milligrams per kilogram (mg/kg) to protect hypothetical subsistence anglers relative to cancer risk to 0.26 mg/kg to protect the average sport angler from reproductive risks (CDM, 2000a).

According to the ERA, mink is the receptor with the greatest potential for risk at the Site (CDM, 1999a). The hazard quotient (HQ; values greater than 1 may indicate an unacceptable risk), which related estimated exposure to a known safe level of exposure, was 62 for mink. The next highest HQ for a fish consumer was 1.5 for bald eagles. In the ERA, CDM calculated two different fish PCB concentrations as potentially protective of mink: a 0.69 mg/kg Lowest Observed Adverse Effects Concentration (LOAEC) and a 0.22 mg/kg No Observed Adverse Effects Concentration (NOAEC) (CDM, 1999a). While these concentrations are applied in this analysis, it should be noted that comprehensive studies of mink are underway by Giesy (2000). These studies are likely to produce more accurate estimates of exposure than the screening-level methods and assumptions used in the ERA, since the latter by design tend to over-estimate risks (CDM, 2000a).

2.2 Identification of ARARs and TBCs

> - There are three broad categories of ARARs:
>   - Chemical-specific
>   - Action-specific
>   - Location-specific
> - There are no federal or Michigan state cleanup standards that relate directly to contaminated sediments.

CERCLA specifies that Superfund remedial actions must comply with applicable or relevant and appropriate requirements of other federal and state environmental laws, or ARARs. A requirement under other environmental laws may either be "applicable" or "relevant and appropriate." Identification of ARARs must be done on a site-specific basis and involves a two-part analysis. First, it is determined whether a given requirement is applicable. If it is not applicable, it is determined whether the requirement is nevertheless both relevant and appropriate.

Applicable requirements include cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, remedial action, location, or other circumstance at the CERCLA site.

Relevant and appropriate requirements include cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not "applicable" to a hazardous substance, remedial action, location, or other circumstance at the CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site such that their use is well-suited to the particular site.

The determination that a requirement is relevant and appropriate is a two-step process: 1) determination if a requirement is relevant; and 2) determination if a requirement is appropriate. This typically involves comparing a number of site-specific factors, such as characteristics of the remedial action, the hazardous substances at the site, or the physical circumstances of the site, with statutory or regulatory requirements. In some cases, a requirement may be relevant, but not appropriate, given site-specific circumstances; such a requirement would not be considered an ARAR for the site. There is also a degree of latitude and discretion in the determination of whether a requirement is relevant and appropriate; it is possible for only part of a requirement to be considered relevant and appropriate in a given case. When the analysis results in a determination that a requirement is both relevant and appropriate, such a requirement must be complied with to the same degree as if it were applicable.

Items to be considered (TBCs) are nonpromulgated advisories or guidance issued by federal or state governments that are not legally binding and do not have the status of potential ARARs. However, in many circumstances, TBCs may be considered along with ARARs in determining the necessary level of remediation for protection of health or the environment.

CERCLA actions should comply with the following three types of requirements:

- *Chemical-specific* requirements are usually health- or risk-based numerical values or methods that, when applied to site-specific conditions, result in the establishment of numerical values that establish the acceptable amount or concentration of a hazardous substance that may be found in, or discharged to, the ambient environment.

- *Action-specific* requirements are usually technology- or activity-based, and may include limitations on actions taken with respect to hazardous substances.

- *Location-specific* requirements are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they occur in specific locations.

The chemical-specific ARARs representing the potential environmental goals of a remedy are related to the levels of PCB in surface waters. There are no federal or Michigan cleanup standards that relate directly to contaminated sediments. However, federal and state laws establish acceptable levels of PCB in surface water as follows:

Law	PCB Level
Clean Water Act, National Toxics Rule (40 CFR 131.36)	0.00017 µg/L (Human Health) 0.00012 µg/l (Wildlife)
Michigan Natural Resources and Environmental Protection Act, Part 4, Act 451 Part 31	0.000026 µg/L (Human Health) 0.00012 µg/L (Wildlife)

Table 2-1 identifies potential ARARs and TBCs, provides a regulatory citation as appropriate, and presents a brief description for each. The table also identifies whether the requirement or guidance applies to any portion of the potential remedial alternatives being evaluated and, if so, whether it is a potential ARAR or TBC. The ability to achieve ARARs will be considered in the development and detailed evaluation of remedial alternatives. In addition, once a remedial alternative has been selected for the Site, additional ARARs may be identified during detailed design.

2.3 Remedial Response Objectives

This section identifies the RROs developed for the Site based on USEPA guidance and experience at similar sites. These RROs pertain to "general site cleanup" or are intended to fulfill potential federal and state ARARs and TBC criteria.

> ➢ "For sediment sites, it is especially important to evaluate how a remedial action will affect any fish consumption advisories, as a frequent exposure pathway is the consumption of contaminated fish by humans and wildlife," (USEPA, 2000a).

As stated in USEPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA, 1988), RROs consist of media-specific or OU-specific goals for protecting human health and the environment. Further, the guidance indicates that constituents of concern, exposure route(s) and receptor(s), and preliminary remediation goals should be specified in the RROs. If future remedial activities may be undertaken at the Site, or if the Site is to be remediated in a phased approach, the objectives also should consider the scope of such future activities. The primary RRO proposed for this Site, where PCB are the (primary) constituent of concern, is as follows:

RRO 1: Reduce PCB concentrations in Kalamazoo River fish to acceptable levels in terms of human health and ecological risk.

Ancillary RROs for the Site are as follows:

RRO 2: Reduce water-column transport of dissolved or particle-bound PCB to Lake Michigan; and

RRO 3: Reduce PCB loading to the Kalamazoo River.

The range of "acceptable" levels of PCB in fish and water can be considered in light of:

- Promulgated standards or generic risk-based criteria;
- Site-specific risk-based criteria; and
- Expected background levels of PCB.

Although no environmental standards exist for PCB concentration in fish, there is a standard for PCB levels in fish sold in commerce and there are some generic risk-based criteria used to set fish consumption advisories. The United States Food and Drug Administration (USFDA) tolerance level for PCB in fish is 2 mg/kg. Generic risk-based criteria that have been developed for use in setting fish consumption advisories in the Great Lakes that are used in Michigan include

0.05 mg/kg, a level which supports unlimited consumption by all segments of the population. At the upper end, no-consumption advisories are triggered when average PCB levels (for women and children) or median PCB levels (for general population) are equal to or exceed 2 mg/kg, respectively. The other Great Lakes fish consumption advisory PCB concentrations and those used by the Michigan Department of Community Health (MDCH) to set fish consumption advisories are described further in Section 6 of the RI Report (BBL, 2000b).

The Michigan surface water quality standard of 0.000026 micrograms per liter (μg/L) was calculated to be protective of human health at a 10^{-5} cancer risk level. Inherent to the calculation is an associated ingested fish PCB concentration of 0.023 mg/kg.

The levels of PCB in fish at the site that would be protective of humans and sensitive ecological receptors were estimated by CDM (2000b, 1999a). Those concentrations for average sport anglers include fish fillet PCB concentrations of 0.042 mg/kg to be protective at the 10^{-5} cancer risk level. Levels of PCB in fish estimated to be protective to the most sensitive ecological receptor (mink) are generally higher than those protective of humans, ranging from 0.22 to 0.69 mg/kg, but apply to whole-body rather than fillet PCB concentrations.

Finally, current and future background levels of PCB merit consideration in setting realistic remedial action objectives. With respect to surface water PCB concentrations, technology is not currently capable of measuring PCB in water samples at the level of the surface water standard. It is noteworthy that background levels of PCB in environments as remote as the northernmost section of Michigan's Keweenaw Peninsula in Lake Superior have snowpack PCB concentrations of approximately 0.002 μg/L; 70 times the Michigan water quality standards (Franz and Eisenreich, 2000). PCB levels upstream of Morrow Dam and the Site are expected to be even higher for many years to come. Data collected by the MDEQ in 1999 detected PCB in surface water at River Street (Comstock) at 11 μg/L. Background PCB concentration in carp fillets from upstream of the Site in Ceresco Lake are in the 0.1 mg/kg range. Morrow Lake average PCB concentration in smallmouth bass and carp fillets are in the range of 0.1 to 0.5 mg/kg. These levels are considerably higher than PCB levels associated with statewide and site-specific criteria estimated for *de minimis* human health risk and water quality standards.

2.4 General Response Actions

> ➢ GRAs identify generic technology types that could be used to achieve the RROs.

GRAs are types of actions that could be used to achieve identified RROs. These actions are identified based upon review and consideration of action-specific ARARs and remedial actions used, or considered for use, at similar sites. GRAs do not identify specific processes or materials to be used, but rather identify generic technology types that could be used individually or in combination. These actions are typically medium-specific. With respect to the Site RROs, the GRAs largely apply to exposed and submerged sediment that would be managed to reduce PCB bioaccumulation in fish. GRAs that could be applied to the Site are grouped into the following 12 categories:

- **No Further Action** - No additional action would be taken. Ongoing natural processes would continue.

- **Source Control** - Reduction in PCB loading from identified external sources including responses to identify and control as yet unidentified sources.

- **Institutional Controls and Monitoring** - Includes administrative controls to limit exposure to media that potentially pose an unacceptable risk. Such controls may include fish consumption advisories and monitoring of PCB levels in fish.

- **Monitored Natural Attenuation** - Includes those natural processes which reduce the bioavailability of sediment chemicals over time and monitoring to gauge the performance of those processes against expectations.

- **In-Place Containment** - Includes the installation of barriers of various materials and thicknesses to isolate affected media from the surrounding environment. Containment options can include submerged sediment caps using soils and various other materials and ongoing deposition of cleaner material.

- **Hydraulic Modification** - Includes modification to existing channels by diversion through man-made structures (e.g., pipes) or through newly excavated channels, construction of sedimentation basins, or other construction or operational methods of reducing the contact of Kalamazoo River water with PCB-containing riverbank and bed sediments.

- **Sediment Treatment** - Includes ex-situ treatment (after removal) or treatment in place (in-situ) of sediment to destroy/detoxify, extract, or immobilize constituents, or reduce the volume prior to disposal of the treated material.

- **Sediment Removal** - Includes removal of sediment using land-based or water-borne equipment, and may be performed "in-the-wet" and/or "in-the-dry" following hydraulic isolation.

- **Sediment Dewatering** - Includes processing removed sediment to reduce the water content and make it more manageable for disposal either on-site or off-site.

- **Sediment Disposal** - Includes the construction or use of landfills or confined disposal facilities (CDFs) to provide permanent storage of removed sediment.

- **Residuals Management** - Includes methods for processing the water or oily residues that may be removed from the sediment during dredging, dewatering, or disposal.

- **Fisheries Management** - Includes actions such as removal and stocking or habitat modification to reduce the relative abundance of fish species containing elevated PCB concentrations (e.g., carp).

2.5 Areas Potentially Subject to Remediation

Having identified GRAs for the Site, the next step in the FS process is to determine which Site areas and media are subject to potential remediation. Determination of areas potentially subject to remediation is based on identifying potential exposure pathways that could result in significant risks to human health or the environment. The HHRA and ERA identified exposure pathways involving the consumption of fish as presenting the most significant potential risk to human health and the environment at the Site. The HHRA also identified hypothetical risks to residents living adjacent to the exposed sediments of the MDNR-owned former impoundments as exceeding MDEQ thresholds. The former impoundments generally consist of wetland areas within the Kalamazoo River floodplain that are owned and managed by the MDNR as low-use recreational areas. Considering the current ownership and limited usage of the former impoundments, and the fact that these are largely wetland areas, it can be assumed that uses of the lands will not appreciably change in the future and that uses such as residential development will be precluded for reasons other than the presence of PCB.

> - Reduction of sources of PCB that impact PCB concentrations in fish is the key.
> - Surficial sediments and the eroding riverbanks in the former impoundments are the primary sources of PCB to the river.

An effective remedy for the Kalamazoo River must focus on the reduction of sources of PCB to fish. PCB in fish derive from internal (to the river) sources, including surficial sediments in the river channel and existing impoundments, and external (to the river) sources, the most important of which are the riverbanks of the MDNR-owned former impoundments. Undercutting of the riverbanks in these areas has resulted in slumping and erosion, causing releases of PCB from these areas to the river. These PCB, as with PCB from other known and unknown external sources within the watershed, are more bioavailable upon entry to the river than much of the PCB already in the river sediment bed that were deposited historically and are now less available for exposure and transport.

The four OUs within the Site already have been, or will soon be, virtually eliminated as potential sources of PCB to the Kalamazoo River. Remedial activities at each OU, described in the RI Report (BBL, 2000b), include the consolidation of residuals into landfills, capping and closing landfills, extraction of residuals from the sediment bed immediately adjacent to some OUs, and the removal of PCB-containing residuals, soils, and sediment from the former Bryant Mill Pond.

Although non-KRSG industrial facility discharges of PCB to the Kalamazoo River have been documented as recently as September 1997, overall wastewater discharges of PCB have been greatly reduced compared to historical levels. Moreover, it is assumed that these sources will be addressed separately by the appropriate non-KRSG parties. For example, as discussed in the RI Report, the nearby Rockwell International Corporation Superfund Site source of PCB to the Kalamazoo River is being addressed under a separate CERCLA action.

The conceptual site model and the results of PCB fate and transport analyses were used to arrive at an approach to determine a potentially effective spatial application of engineered remedial alternatives. Effectiveness is viewed primarily as the degree of risk reduction and corresponding post-remedial residual risk level achieved by reducing fish PCB concentrations. This FS focuses on PCB levels in surface sediment as a surrogate and indicator of PCB concentrations in fish. This assumption is supported by the RI results and the scientific literature regarding the accumulative of PCB in fish. Additional tools and measures of effectiveness are presented in detail in the *Supplement to the Kalamazoo River RI/FS* (BBL, 2000c).

Site data and results of system analyses were evaluated to assess whether concentrating remedial effort within a relatively small portion of the Site would significantly reduce potential exposure to PCB. The relative importance of external source loading, PCB transport from upstream areas, where people are fishing, and the factors regulating PCB concentrations in fish were scrutinized in assessing ways to efficiently achieve the greatest reduction of PCB concentrations in fish.

> ➢ There does not appear to be any opportunity to reduce PCB concentrations in fish by focusing remedial efforts on a relatively small section of the river.

Given the general nature of river systems and the particular angling practices on the Kalamazoo River, targeting the reduction of fish PCB concentrations in a relatively small area (e.g., just upstream to just downstream of an area used for angling) would have limited risk reduction benefits. The Agency for Toxic Substances and Disease Registry's (ATSDR's) (2000) observations note that most angling in the Kalamazoo River occurs in parks located in Comstock and Kalamazoo, and in Lake Allegan. These locations span the Site, and the surface area of Lake Allegan exceeds the rest of the river combined. Also, there are no barriers to upstream fish movement within the 22-mile section of River from Morrow Dam to the Plainwell Dam (which includes popular fishing sites in Comstock and Kalamazoo). Consequently, the pattern of angler activity indicates limited, if any, opportunity to reduce exposure of the fish-eating population by targeting relatively small areas for remediation to reduce fish PCB concentrations in those small areas.

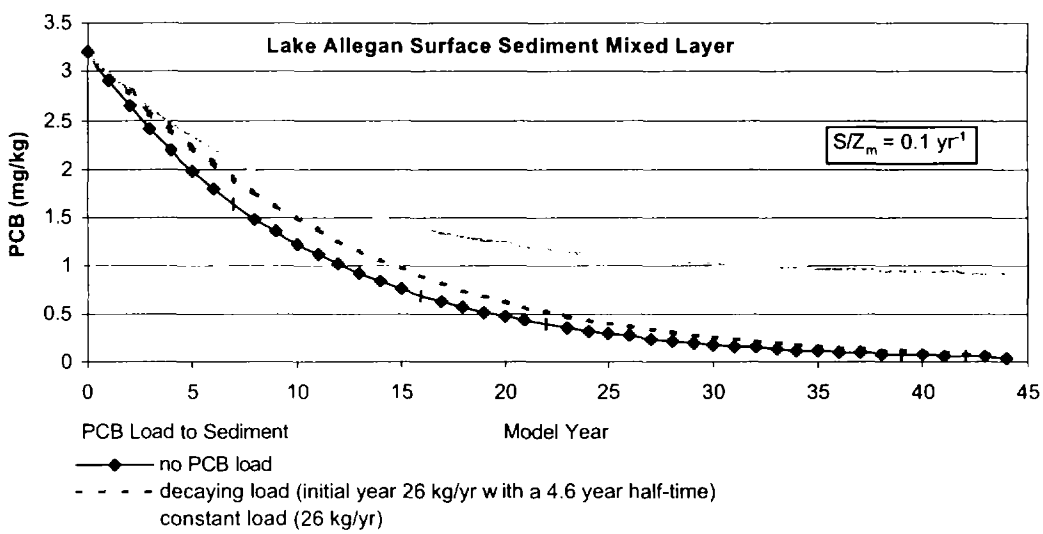
The relative effectiveness of engineering controls (e.g., capping, dredging) to reduce surface sediment PCB concentrations, and thus exposure, in any discrete area of the river must be judged based upon the following:

- The extent to which PCB levels currently in an area will sustain PCB concentrations in fish in that area in the future;
- The extent to which future transport from an area will affect concentrations in fish found in downstream areas; and
- The extent to which fish PCB concentrations in an area will be sustained in the future by PCB transport from upstream areas.

To address these issues, the estimated benefit of remediating individual reaches between Morrow Lake and Lake Allegan was evaluated through systems analyses. The analyses included: 1) the application of a simple mass balance model for the mixed layer of sediments in Lake Allegan; 2) consideration and comparison of the relative magnitudes of measured PCB transport, estimated PCB loading from the former impoundment riverbanks, and the inventory of PCB found in various layers particularly the surface sediments in various sections of the river; and 3) a preliminary assessment of the erosion potential for sediments in the current and former impoundments. More robust assessment tools and additional empirical measurements are presented in the *Supplement to the Kalamazoo River RI/FS*.

A simple mass balance analysis of the Lake Allegan sediment bed provides some insight into how the lake sediments would respond to remediation of sediments upstream. The importance of Lake Allegan is evident by its size, comprising roughly two-thirds of the river surface area downstream of Morrow Dam, and the fact that it attracts anglers that could be exposed through fish they catch and then consume (ATSDR, 2000). The mass balance provides a representation of the surface mixed layer of sediments in Lake Allegan and illustrates the range in future surface sediment PCB concentration for different assumptions about PCB loading; results are presented in the following figure. The ratio of Lake Allegan sedimentation rate to thickness of the surface sediment mixing layer ($S/Z_m = 0.1$ year^{-1}, see RI Report for calculation details) produces an intrinsic half-time of 6.9 years and results in the curves shown in the following figure based on three potential scenarios assumed to begin in 1994:

1) A constant future PCB loading rate of 26 kg/year;
2) An initial PCB loading rate of 26 kg/year that declines at a rate associated with a 4.6 year half-time (0.15 year^{-1}); and
3) The response if all of the upstream load of PCB were instantly eliminated in 1994.

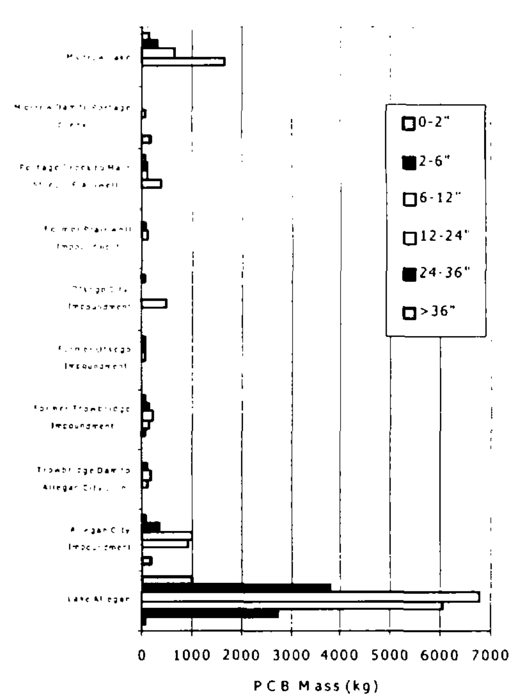


The sharp drop in the three curves during the first several years is attributable to the relatively wide span between the mass of PCB already in the mixed layer compared to the small amount of annual PCB load to the sediment. The PCB mass loading to the mixed layer implied by deposition of sediment in Lake Allegan with a 1 mg/kg concentration is approximately 29 kg/year. This contrasts to an estimate of 930 kg in a 5-cm mixed layer based upon 3.2 mg/kg PCB concentration in the mixed layer. However, as time progresses and mass of PCB in the mixed layer becomes smaller due to burial. the PCB load, if it remains constant, exerts increasingly greater and greater control on the PCB levels in surface sediments. This eventually approaches the assumed constant PCB concentration of the depositing sediments. If the load continues to decline at the rate of 0.15 $year^{-1}$ (4.6 year half-time), then little difference exists between the curve for hypothetical PCB load elimination and that for the declining PCB load.

These simple PCB mass balance results for Lake Allegan have implications for potential remedial approaches. First, if PCB loading from the banks of the MDNR-owned former impoundments (which contribute somewhere between 10 and 100 kg of PCB annually to the Kalamazoo River) supplies even a relatively small amount of PCB (e.g. 10 to 20 kg annually) to Lake Allegan sediments over the long term, the effects of underlying natural attenuation processes in the lake would be stalled as PCB concentrations in the mixed layer would reach a steady-state level. This steady-state level would be in the neighborhood of 0.4 to 0.8 mg/kg. If, on the other hand, all upstream PCB loads were to decline at the current rate, natural attenuation could be expected to reduce sediment PCB levels progressively to approximately the same levels that would be hypothetically achieved if all upstream sources were instantly eliminated. These results point to the priority for identifying, quantifying, and controlling upstream sources of PCB. Such sources include the channel sediments, eroding banks of the MDNR-owned former impoundments, and other unquantified external sources upstream of the Site or within the watershed.

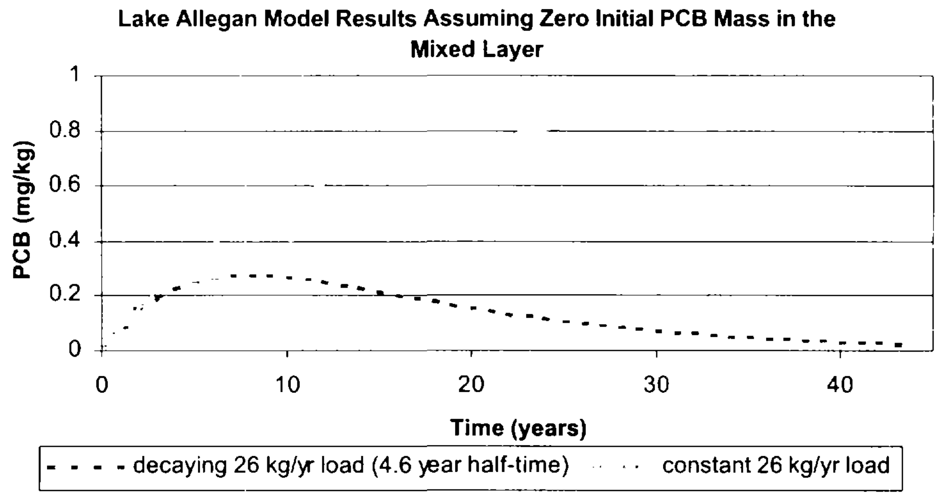
The amount of annual PCB transport contributed by sediments in the channel of the various studied river sections and the riverbank deposits cannot be empirically determined with high accuracy based on existing data. During 1994, PCB transport through the Site was estimated to range from 10 to 26 kg/year, increasing from roughly 12 kg/year at Michigan Avenue in Kalamazoo to 28 kg/year at Farmer Street in Otsego. Estimates of bank loading of PCB are in the range of 10 to 100 kg/year to the river over the three MDNR-owned former impoundments. Bank loading of PCB is known to occur by direct observation. Although other external PCB loading is expected to be comparatively small, the exact proportion of current measured transport that is attributable to these sources is unknown.

Some indication of the potential amount of PCB export from each section of the river channel is reflected in the mass of PCB found in surface sediments. PCB mass estimates in the various sections of the river are presented in the figure on the right. For the sections between Morrow Lake and the Allegan City Impoundment, PCB mass in surface sediments (0-2 inches) varies from 24 kg to 96 kg, while the PCB mass in sediments over all depths varies from 240 to 750 kg. The quantity of PCB in the Allegan City Impoundment surface sediments is relatively small (82 kg). The quantities of PCB in Allegan City Impoundment (2,500 kg) and Morrow Lake (2,900 kg) are relatively large by comparison. For comparison purposes, according to the RI, a 5-foot width of the stream banks in the three former impoundments collectively contains roughly 800 kg of PCB (BBL, 2000b).



The ability of upstream reaches to recontaminate the surface of an actively remediated reach is suggested by the comparable magnitude of annual transport and PCB mass contained in surface sediments. As illustrated quantitatively in the following paragraphs, this even applies to Lake Allegan where the ratio of annual PCB transport to the amount of PCB in the mixed layer is the smallest.

The figure below shows the results of applying the simple mixing-layer mass balance model ($S/Z_m = 0.1$ year^{-1}) to a hypothetically and completely remediated Lake Allegan. The hypothetical remediation is an instantaneous elimination of all of the PCB from the mixed layer at time zero ($C_0 = 0$). Two different conditions regarding continued PCB transport from upstream were considered: 1) the condition of PCB loading to the bed continuing at a rate of 26 kg/year; and 2) the condition of PCB load decreasing at a rate of -0.15 year^{-1} (4.6 year half-time).



Results show the extreme range of possible future responses. Even with a diminishing PCB load, recontamination to greater than 0.1 mg/kg is predicted. As evident by the uppermost curve and previously described by the model, if PCB loading is not reduced over time, a steady-state PCB concentration of approximately 1 mg/kg would be achieved.

The results of the systems analysis show that the annual PCB transport observed during 1993/1994 was a small percentage of PCB in the surface sediments of Lake Allegan (2.6%), but a much larger percentage of PCB in the surface sediments of individual sections upstream of Lake Allegan (27 to 100%) and below Morrow Lake. This indicates a higher sensitivity of surface sediment PCB concentrations in the individual sections to transport from upstream reaches when compared to Lake Allegan. However, even Lake Allegan is somewhat sensitive to the future PCB loading in the Kalamazoo River.

In summary, the system analyses indicate:

- A reduction in the PCB loading from the banks of the MDNR's former impoundments will likely result in the greatest downstream response (in terms of reduced PCB levels in surface sediment); and
- Future PCB levels in surface sediments of an individual section will likely be determined by PCB transport from upstream and PCB already within the section, among other factors.

These observations support: 1) conceptualizing of remedial alternatives to control PCB loading from the banks of the MDNR's former impoundments; and 2) conceptualizing remedial alternatives in a bank-to-bank fashion, working upstream to downstream (to reduce PCB loading to downstream areas and reduce exposure to PCB in that area). At this level of analysis the results also leave open the possibility that PCB transport from Morrow Lake could undermine downstream remediation if transport does not diminish over time.

Inside Section 1 – Introduction
Inside Section 2 – Development of Remedial Response Objectives & General Response Actions

Inside Section 3 – Evaluation of Remedial Technologies and Development of Potential Remedial Alternatives

Inside Section 4 – Detailed Evaluation of Remedial Alternatives
Inside Section 5 – Comparative Analysis of Remedial Alternatives
Inside Section 6 – Preferred Remedy

☛ ***The evaluation of remedial technologies is carried out in three steps.***

❶ First, a wide array of potential technologies and specific process options are considered to see whether each one is applicable, feasible, and readily available.

❷ Second, all the remedial technologies and specific process options retained after step one are evaluated based on overall effectiveness, implementability, and relative cost.

❸ Finally, those retained after step two are assembled into proposed remedial alternatives, which are compared and evaluated in Sections 4 & 5.

<table>
<tr><th>Step ❶</th><th>Step ❷</th><th>Step ❸</th></tr>
<tr><td>66 different process options in 12 technology categories were evaluated. 32 process options were screened out and not considered further. All technology types were retained except for Fisheries Management.</td><td>25 of the 34 process options retained after step 1 were retained after the second step – these are the options that are assembled into remedial alternatives in step 3.</td><td>5 remedial alternatives were assembled from the process options retained after step 2. Detailed evaluation of these alternatives is presented in Sections 4 & 5.</td></tr>
<tr><th>TECHNOLOGY TYPES</th><th>PROCESS OPTIONS</th><th>REMEDIAL ALTERNATIVES</th></tr>
<tr><td>No Further Action</td><td>No Further Action</td><td rowspan="13">1. No Further Action

2. Institutional Controls & Monitoring

3. Bank Stabilization at the Former Impoundments, Monitored Natural Attenuation, and Institutional Controls

4. River-Wide Capping of Submerged Sediments, Bank Stabilization at the Former Impoundments, Institutional Controls, and Monitoring

5. River-Wide Dredging of Submerged Sediments with Upland Confined Disposal, Bank Stabilization at the Former Impoundments, Institutional Controls, and Monitoring</td></tr>
<tr><td>Source Control</td><td>Identification of External Sources
Bank Stabilization</td></tr>
<tr><td>Institutional Controls and Monitoring</td><td>Consumption Advisories
Pool Elevation Control
Monitoring</td></tr>
<tr><td>Monitored Natural Attenuation</td><td>Natural Processes</td></tr>
<tr><td>In-Place Containment</td><td>Engineered Capping/Armoring
Particle Broadcasted Cap
AquaBlok™ Cap</td></tr>
<tr><td>Hydraulic Modification</td><td>Rechannelization</td></tr>
<tr><td>Sediment Treatment</td><td>Biodegradation, In-Situ</td></tr>
<tr><td>Sediment Removal</td><td>Mechanical Dredging
Hydraulic Dredging
Amphibious Dredging</td></tr>
<tr><td>Sediment Dewatering</td><td>Plate and Frame Filter Press
Belt Filter Press
Solid Bowl Centrifuge
Evaporator
Hydrocyclone</td></tr>
<tr><td>Sediment Disposal</td><td>Confined Disposal Facility
TSCA-Regulated Landfill
Solid Waste Landfill
On-Site Landfill</td></tr>
<tr><td>Residuals Management</td><td>Activated Carbon Adsorption
Filtration</td></tr>
<tr><td>Fisheries Management</td><td>no options retained</td></tr>
</table>

3. Evaluation of Remedial Technologies and Development of Potential Remedial Alternatives

3.1 Overview

> - The development of remedial alternatives involves three steps, which are summarized in this section.
> - First, a wide array of potential technologies are considered to see whether they are applicable, feasible, and available.
> - The remedial technologies retained after step one are evaluated based on overall effectiveness, implementability, and relative cost.
> - Finally, those retained after step two are assembled into proposed remedial alternatives, which are compared and evaluated in Sections 4 and 5.

This section identifies and screens potential remedial technologies and process options, and develops potential remedial alternatives for the Site. Potentially applicable remedial technologies are evaluated in two steps, in accordance with USEPA guidance (1988). First, a wide array of possible remedial technologies is evaluated based on the potential for technical implementability at the Site given RI information on constituents, media of concern, and site characteristics. Technologies that cannot be technically implemented are eliminated. Next, the remedial technologies that have not been eliminated are further evaluated based on overall effectiveness, implementability, and relative cost (USEPA, 1988). Representative technologies retained following this screening step then are assembled into potential remedial alternatives that are screened a final time. Following this final screening step, the remaining alternatives are evaluated in detail and then compared in Sections 4 and 5, respectively.

The AOC requires that potential response objectives for each affected medium and a preliminary array of remedial alternatives and associated technologies be identified before conducting the RI. This process was intended to create a general classification of potential remedial alternatives based upon the potential chemical migration pathways and potential public health and environmental impacts, using the information on those topics that was available at the time. The list of preliminary remedial technologies identified at the time of the writing of the RI/FS Work Plan (BBEPC, 1993c) is provided in Table 3-1. This list was used to guide the collection of appropriate data during the RI.

As stated in the USEPA guidance (1988), preliminary remediation goals are reevaluated as site characterization data and information from the baseline HHRA (CDM, 2000b) and ERA (CDM, 1999a; 2000a) become available. As discussed in Section 1.4 of this FS, groundwater, soils, and surface water pathways do not present risks warranting remedial responses. Therefore, by taking into consideration the RI data and the latest information on the various applicable technologies, a revised set of potentially applicable remedial technologies was developed as described in the following section.

3.2 Identification and Screening of Remedial Technologies and Process Options

Based on the Site-specific GRAs defined in Section 2.4, potential technology types and process options associated with each GRA have been compiled. "Technology types" are considered as general categories of technologies, while "process options" refer to specific processes within each technology type (USEPA, 1988). For example, dredging is a technology type under the more general sediment removal GRA, and mechanical dredging is a process option under dredging.

- An extensive array of potential remedial technologies was considered for use at the Kalamazoo River, including 66 specific options among 12 different categories.
- Table 3-2 lists all the technology types and process options considered during this first screening step.

As noted above, technology types and process options are first evaluated only on the basis of technical implementability at the Site. In this step, the evaluation of technical implementability is a general, non-detailed consideration of whether a technology type or process option is applicable with respect to specific Site conditions, whether implementation is feasible, and whether the technology has been fully developed for use. This analysis is based on information from a variety of sources, including general knowledge and experience at the Site, experience gained from other similar sites, and the literature. This initial screening step reduces the number of potential remedial technologies that will undergo a more rigorous evaluation.

Table 3-2 summarizes the identification and screening of potential remedial technologies and process options that could reasonably be applied to submerged sediments and river banks that are potentially subject to remediation within the former impoundments. Technologies and process options that may be applied to the exposed sediments in the former impoundments are not identified on this table because, as discussed in Section 2.5, these areas have not been conclusively determined to pose a risk, and the remedial management of the exposed sediments is not necessary to address the established RROs. (Remedial technologies for these areas are appropriately presented in the development of remedial alternatives in subsequent sections of this FS.) The first column of the table identifies GRAs with several broad technology types, and associated process options that may be used for different stages of response actions are provided in the second column. This table also provides a brief description of each process option, along with a preliminary assessment of technical implementability. Process options that are shaded in Table 3-2 do not meet the technical implementability criteria as described above and, therefore, are not retained for further evaluation.

3.3 Remedial Technologies Evaluation and Selection of Representative Process Options

> - During this next step, potentially promising technologies are further evaluated based on effectiveness, implementability, and cost.
> - Table 3-3 lists the 25 specific options retained for assembly into remedial alternatives.

Process options retained in Table 3-2 (i.e., those not shaded) are further evaluated based on the expanded criteria of overall effectiveness (ability to meet RROs, implementation effects, and reliability), implementability (technical and administrative), and relative cost (USEPA, 1988). The various process options within a particular technology type are evaluated against other processes in the same technology type. As a result, where appropriate, a minimum of one process option from each technology type is retained for the development of potential remedial alternatives. Selection of a representative process option is not intended to eliminate other retained process options in a technology type from possible use; it is simply intended to streamline the development of potential remedial alternatives. A process option not selected as representative still could be considered during remedial design if its technology type were part of the selected remedial alternative. The criteria used to evaluate the selected representative process options are described below.

Effectiveness

Per USEPA (1988) guidance, the potential effectiveness of each process option is evaluated with respect to:

- The degree to which site risks are reduced and RROs achieved;
- Potential impacts to human health and the environment during the construction and implementation phase;
- Time until risks are reduced to acceptable levels and RROs are achieved; and
- Reliability with respect to the constituents of interest and Site conditions.

Knowledge of the effectiveness of these process options at other relevant sites and previous experience with activities addressing the Kalamazoo River and Portage Creek source areas are also considered in evaluating effectiveness.

Implementability

Implementability encompasses both the technical and administrative feasibility of implementing a process option (USEPA, 1988). As described previously, technical implementability is the primary focus in the initial screening. The second step places greater emphasis on the administrative aspects of implementability, including:

- Ability to obtain necessary approvals;
- Availability of treatment, storage, or disposal services; and
- Availability of necessary materials, equipment, infrastructure, and personnel.

The need to obtain permits was not included as an administrative aspect of implementability at this stage because, according to 40 CFR 300.400, "no federal, state, or local permits are required for on-site response actions conducted pursuant to CERCLA sections 104, 106, 120, 121, or 122." The term "on-site" refers to the Site "and all suitable areas in very close proximity . . . necessary for implementation of the response action."

Cost

Relative costs (i.e., high, low, or moderate) are identified so that a comparative evaluation of process options within each technology type can be made. This relative-cost comparison is made because true cost comparisons cannot be made between different remedial technologies or GRAs at this point in the FS process as full alternatives have not been developed for cost estimating purposes. In addition, certain technology types (e.g., sediment removal and sediment dewatering) can only be used in combination with other technology types to form a remedial alternative and depend on the quantity of media being addressed. Other technology types (e.g., no further action, institutional controls) are not dependent on the implementation of other technology types and can, therefore, be considered independently.

The results of the second phase of screening potential remedial technologies and process options in terms of effectiveness, implementability, and cost are presented in Table 3-3. Based on the two-step evaluation and technology screening process, representative process options for each technology type and for each medium were retained for incorporation into potential medium-specific remedial alternatives and further evaluation. The no further action GRA was kept for use as a baseline against which other remedial alternatives are evaluated. This approach is consistent with state and federal guidance and is required by the NCP. The results of the screening performed in Table 3-3 are presented below.

3.3.1 No Further Action

> ➢ To reduce risks, the "no further action" option relies on the power of natural processes known to be active within the Kalamazoo River.

This GRA does not include any active remedial measures, monitoring, or other controls (including fish consumption advisories) for the Site beyond those that have already taken place (i.e., remedial activities at OUs and other source control measures). This alternative includes ongoing natural attenuation processes (see Section 3.3.4 below) that reduce PCB levels in fish, water, and bioavailable zone sediments over time. No monitoring is included to track the performance of these processes in achieving objectives at the expected rate.

3.3.2 Source Control

The Source Control GRA includes two process options which are retained for inclusion in potential remedial alternatives for the Site: identification of external sources and bank stabilization.

As mentioned previously in this FS Report, non-KRSG industrial facility discharges of PCB to the Kalamazoo River have been documented as recently as 1997. Section 4.7 of the RI Report discusses the number of companies and facilities that were identified from publicly available records as having purchased or discharged PCB in the Kalamazoo River watershed. To be able to adequately address the effects these continuing sources of PCB have on the Site, an investigation into these sources would be conducted, and appropriate control measures put into place to eliminate them.

In portions of the former impoundments, scouring of exposed sediments deposited along the banks of the Kalamazoo River is evident from observations made during the collection of data during the RI. The sloughing of these sediments into the river represents the largest identified current external source of PCB to the Kalamazoo River (see Section 5.3.1.1 of the RI Report). Placement of an erosion control layer over the exposed sediment banks in the former impoundment areas, therefore, may provide exceptional benefit relative to other GRAs and process options in efforts to meet the RROs. This layer may include placement of riprap material along the riverbank to increase stability and decrease the erosion potential of exposed sediment areas.

The process options of source identification and bank stabilization, under the Source Control GRA, are evaluated with respect to effectiveness, implementability, and cost in Table 3-3.

3.3.3 Institutional Controls

> - Institutional controls reduce risks by limiting human or ecological exposure to PCB.
> - Examples include annual fish consumption advisories issued by the MDCH, maintaining dams and water levels in impoundments, and monitoring PCB concentrations and movement over time.

For this GRA, all of the process options listed on Table 3-3 have been retained for inclusion in potential remedial alternatives for the Site. These process options are distinctively different from each other and hence are carried through this screening phase so that all technology types are represented. The retained process options include access restrictions, deed restrictions, fish consumption advisories, pool elevation control, and monitoring of site media.

Fish consumption advisories are currently in-place at the Site and reduce exposure to fish tissue PCB through restrictions on consumption. Access restrictions would limit public entry into areas used for fishing to mitigate the taking and consumption of fish. Deed restrictions would inform property owners of legal constraints to land use as an adjunct response action to facilitate the long-term integrity of the remedy. Pool elevation controls, which are in practice at some locations, would be implemented by the dam owners to minimize the potential for scour, resuspension, and transport of buried PCB-containing sediments that are impounded behind existing dam structures, and mitigate the potential for consequent uptake of PCB by fish. Periodic sampling and analysis of fish would provide data to determine when the advisories may be relaxed and eventually eliminated. An appropriately detailed monitoring plan would be developed during the remedial design phase.

An assessment of the relative effectiveness, implementability, and cost of each process option retained under the institutional control GRA is presented in Table 3-3.

3.3.4 Monitored Natural Attenuation

> - Monitored natural attenuation relies upon the physical, biological, and chemical processes already at work in the Kalamazoo River to reduce risks.
> - These natural processes are intensively monitored to track their effectiveness over time.

Natural attenuation, or natural recovery, involves "leaving the contaminated sediments in place and allowing the ongoing aquatic processes to contain, destroy, or otherwise reduce the bioavailability of the contaminants" (National Research Council [NRC], 1997). Unique to natural attenuation as a remedial alternative is its ability to reduce chemical exposure, toxicity, or mobility through ongoing natural processes. These natural processes occurring in aquatic systems can be categorized into physical, biological, and chemical mechanisms.

Physical Processes - The in-place covering and mixing of contaminated sediments with progressively cleaner sediments delivered by erosion and deposition within the watershed is the major fate mechanism for persistent chemicals in sediment. Through this burial process, contaminants deposited in the past are gradually buried deeper in the sediment bed and, therefore, farther away from the dynamic sediment surface, where they could be available for uptake by the food web or downstream transport in the water column. The rate of sediment deposition and the vertical extent of sediment mixing are key parameters determining the rate of change of contaminant levels in surface sediments. The greater the deposition rate and the thinner the mixed layer, the faster the levels of contaminants in surface sediment are reduced.

Dispersion, recognized as a mechanism of natural attenuation for groundwater (USEPA, 1999), is also a mechanism of natural attenuation for contaminated sediments. For coarse sediment substrates, where both rates of net sediment accumulation and bulk sediment chemical concentrations may be low, dispersion may be the predominant long-term process reducing the availability of sediment contaminants. Sediment-borne chemicals are thereby transported to lower energy areas, where they are mixed with and covered by progressively cleaner sediments. As evident in the results of the modeling of PCB fate, this appears to have been explicitly recognized by the USEPA (1994a) in the selection of natural attenuation for the remediation of Twelvemile Creek and the upper sections of Lake Hartwell, South Carolina. It is also noteworthy that the National Oceanic and Atmospheric Administration's (NOAA's) (1996) guidance for restoring riverine sediments from oil contamination includes not only natural attenuation, but also sediment agitation, which works by actively dispersing oil products from sediment to reduce their concentrations.

Biological and/or Chemical Processes - Chemical and biological mechanisms of natural attenuation are mainly contaminant-specific. For PCB, both aerobic and anaerobic biodegradation processes can degrade PCB compounds in sediments (Abramowicz, 1990). In aerobic sediments, PCB can be degraded through a cometabolic process, although the process is generally limited to PCB congeners having four or fewer chlorines (Untermann, et al., 1987). Anaerobic dechlorination of PCB occurs in marine sediment (Brown and Wagner, 1990) and freshwater sediment (Quensen et al., 1988; Brown et al., 1987a, 1987b). The removal of meta- and para-chlorine on the PCB molecules during anaerobic dechlorination detoxifies PCB in anaerobic sediment (Brown and Wagner, 1990; Tiedje et al., 1993). Dechlorination processes are also discussed under the Sediment Treatment GRA (Section 3.3.7)

In recognizing the capacity of aquatic systems to naturally recover from the effects of contaminated sediments, the USEPA has identified a potential role for natural recovery as a sediment management tool. This was set forth as a guiding principle in its *Contaminated Sediment Management Strategy* (USEPA, 1998):

> "Where short-term and long-term risks and effects are determined to be acceptable, and where statutes or international agreements do not require remediation or establish other preferences (e.g., preference for treatment under the Superfund Amendments and Reauthorization Act of 1986), the appropriate treatment of a contaminated sediment site may be to implement pollution prevention measures and source controls, and to allow natural processes such as biodegradation, chemical degradation, and the deposition of clean sediments to diminish risks associated with the site to within acceptable levels."

The USEPA has applied this principle and selected natural attenuation as a remedial alternative at other PCB sediment sites, including Sangamo Weston, Inc./Twelvemile Creek/Lake Hartwell, and Commencement Bay/Nearshore Tideflats - Hylebos Waterway Superfund Sites.

An evaluation of the monitored natural attenuation GRA with respect to its effectiveness, implementability, and cost is presented along with similar evaluations of other GRAs in Table 3-3.

3.3.5 In-Place Containment

For this GRA, two containment technologies were considered: capping and erosion control. Each of these technologies and associated process options is discussed below.

> - In-place containment reduces risk by isolating PCB-containing sediments or soils under a natural or engineered barrier.
> - The cap contains the PCB in place to prevent movement or erosion.

Retained process options associated with capping and erosion control include natural sedimentation (i.e., the isolation of PCB-containing material through covering and mixing with progressively cleaner material), particle broadcasting, capping using an engineered cover, and erosion control that limits sediment migration through containment. These process options are similar in that each results in existing submerged and/or exposed bank sediments being covered by new materials to reduce PCB availability at the surface. The placement of an erosion-control layer is only applicable to the bank areas of the former impoundments. Natural sedimentation, particle broadcasting, capping, and erosion control are all retained for further evaluation.

The natural sedimentation option is applicable to all areas where progressively cleaner materials deposit over, or mix with, existing materials in submerged areas. This in-place containment option is potentially applicable to submerged sediments throughout the entire Site, and is also a component of the monitored natural attenuation processes discussed in Section 3.3.4.

Particle broadcasting lends support to the natural recovery process by speeding up the rate at which sedimentation occurs. This process involves the addition of fine particles (such as silt) to increase the total suspended solids (TSS) in the water column. This would serve to increase both sediment deposition and mixing at the Site, and decrease the surficial PCB concentration in submerged sediment, thus reducing PCB bioavailability. Particle broadcasting has been used at sites such as the Pier 64 Capping Project in Seattle, Washington.

An engineered cap involves the placement of single or multiple layer(s) of clean, natural material (e.g., sand, gravel) over in-situ PCB-containing material according to a design objective of chemical and biological isolation and erosion control (Figure 3-1). Given the surface area of the Site, construction of an engineered cover over these areas would require placement of millions of cubic yards (cy) of material and would destroy the existing vegetation and benthic communities inhabiting these areas. Low-impact placement of the cap material, the use of geotextiles, and the procurement of compatible geologic materials (such as other fine sediment/silt), as well as other options, could be explored to address issues of implementation effects.

Technologies under the in-place containment GRA are evaluated along with the other GRAs with respect to effectiveness, implementability, and cost in Table 3-3.

3.3.6 Hydraulic Modification

> - Hydraulic modification involves making significant physical changes to the river channel.
> - Implementation is not feasible on a large scale so this approach is not considered further.

Rechannelization and sedimentation basins have been retained through the initial screening steps as process options representative of hydraulic modification technologies. Rechannelization would involve the creation of new channels to eliminate fish exposure to PCB-containing material in specific areas. The existing river channel would be filled in to contain existing PCB-containing sediment. Sedimentation basins would involve widening existing channel banks in select areas and/or installation of dams to reduce flow velocities in the Kalamazoo River. Lower velocities in flowing systems result in natural deposition of sediments in the water column.

Constructing an entirely new river channel along the Kalamazoo River would be a difficult engineering endeavor. This technology typically has been applied at small sites that tend to be located in rural environments, with low-flow rivers or streams containing localized "hot spots." At these sites, hot spots may be circumvented via construction of a new channel or channel section. As described in the RI Report (BBL, 2000b), PCB sediment concentrations in the Kalamazoo River are relatively evenly distributed with no true "hot spots."

River flow could be a problem, since the daily mean flows (for the period of record at each gage station) range from 894 cubic feet per second (cfs) at the Comstock gage station to 1,481 cfs at Fennville, but the corresponding 10-year and 100-year events at Comstock are 4,700 cfs and 6,900 cfs, respectively. To appreciate the scope of rerouting a 1-mile stretch of the Kalamazoo River's 50-mile impacted stretch, approximately 270,000 cy of soil would need to be removed creating a new channel typically 180 feet wide and 7 feet deep, respectively. This assumes, based on observations made along the free flowing river reaches, the need for 3-foot high banks above measured water elevations (BBL, 1994). Although it may be problematic to identify an alternative location for the channel in the more urbanized reaches of the river, there are substantial areas of the river that pass through rural areas where new channels could be constructed. It is expected that significant implementability issues may arise in extending tributary flow sources to the new channel in a manner that would be stable with respect to expected flow ranges, and reliable in the long term.

Like the rechannelization option, the construction of sedimentation basins was not retained as a remedial alternative. Within the current 35-mile stretch of the Kalamazoo River from the Morrow Dam to Lake Allegan, there are four large impoundments formed by the operational dams, including the Lake Allegan impoundment at the most downstream portion of the Site. In addition, the dam remnants owned by the MDNR also impound surface water and sediment on a smaller scale. These impoundments serve to capture PCB-containing sediments that may be resuspended during high flow events and construction of an additional basin is unlikely to provide a significant incremental benefit.

It is anticipated that any hydraulic modification option for the Site would face several major obstacles that would make these impractical. These obstacles would likely include strong public opposition (particularly from affected landowners) and potentially severe environmental consequences, including substantial disturbance of the ecological habitat and the surrounding area, and the destruction or disruption of the benthic community. The substantial value of labor and materials required for these efforts also would likely make these options expensive. Based on the inherent difficulties associated with hydraulic modification options, these options will not be included in the assembly of potential remedial alternatives. An assessment of the hydraulic modification GRA is presented, along with the other GRAs, in Table 3-3.

3.3.7 Sediment Treatment

Four types of in-situ and ex-situ sediment treatment process options were considered through the first two steps of the screening process. These process options include biodegradation, solidification/stabilization, the Soil Tech Anaerobic Thermal Processor process, and incineration. The evaluation of in-situ and ex-situ treatment process options with respect to effectiveness, implementability, and cost is presented in Table 3-3.

> - Treatment technologies reduce risks by degrading or destroying PCB in place or at off-site facilities.
> - The implementation and cost of off-site treatment technologies limit their ability to be more effective than containment of PCB in-place or in landfills.

The only in-situ treatment process option initially retained for further consideration is PCB biodegradation. PCB biodegradation is a change of the PCB molecule as a result of biological processes such as dechlorination and metabolism. PCB biodegradation has been noted at a number of sediment sites (Abramowicz, 1990). Despite its widespread occurrence, ease of implementability, lack of implementability effects, and low cost, biodegradation is not being retained as a self-standing technology. This is because PCB biodegradation is not expected to be effective alone, as detailed below. It will be of some minor additional benefit in concert with other natural processes and/or response actions.

In 1994 and 1995 a biotreatability study was conducted for the Kalamazoo River sediments on behalf of the KRSG (Envirogen, 1995). Two alternative technologies were evaluated at laboratory bench scale: aerobic bioslurry treatment and anaerobic in-situ treatment. The aerobic treatability study involved evaluations of three different test conditions:

1) biostimulation by way of addition of nutrients only, 2) biostimulation with nutrients plus biphenyl, and 3) bioaugmentation by way of addition of nutrients, biphenyl, and Envirogen's proprietary PCB-degrading bacteria. The anaerobic treatability study was conducted either by addition of a carbon source (i.e., chitosan, leaf mulch, or guar gum) or by addition of an active PCB-dechlorinating sediment amendment (i.e., anaerobic microbes).

The results of this study showed that aerobic bioaugmentation reduced PCB concentrations in the Kalamazoo River sediment from 18.1 mg/kg to 5.5 mg/kg (a 70% reduction). Biostimulation by addition only of nutrients and biphenyl reduced PCB concentrations to 7.6 mg/kg (a 58% reduction). Biostimulation by addition of nutrients alone showed only a marginal PCB degradation (35%). This shows that PCB were degraded to a higher extent when PCB-degrading microorganisms were included in the amendment. Also, greater degradation was observed for the lower-chlorinated PCB congeners containing two or three chlorines.

The results of the anaerobic treatability study showed no stimulation of PCB-dechlorination in the Kalamazoo River sediment. The possibility that the Kalamazoo River sediment samples were inhibitory to PCB dechlorination was evaluated by conducting a second anaerobic test, in which an anaerobic sediment that contained actively dechlorinating bacteria was mixed with Kalamazoo River Sediment. The results of this study indicate that the activity of PCB-dechlorinating bacteria was not inhibited when exposed to Kalamazoo River sediments (Envirogen, 1995).

Based upon the results of the treatability study, in-situ PCB biodegradation is rejected as a process option. The aerobic and anaerobic treatments would require a high degree of management in any field applications for a relatively limited treatment efficiency.

The ex-situ treatment technologies retained from Table 3-2 have been screened out and are not included in the assembly of remedial alternatives. These technologies are not further considered because PCB levels in sediments are generally very low relative to the levels where treatment is effective and has typically been applied. Additionally, whether removed sediment is simply landfilled or treated, it provides no additional improvement relative to the Site over any other option involving removal. That is, the fate of the removed material, whether treated or not, has no effect on risks at the site from which material is removed. Ex-situ treatment would have to be used in conjunction with other technology types (e.g., removal, dewatering, and residuals management) for remediation and would significantly and unnecessarily increase the magnitude and cost of the remediation effort. In addition, the implementability of ex-situ treatment may be affected by the limited availability of specialized equipment, material characteristics, and personnel required to implement these complex and time-consuming processes.

3.3.8 Submerged Sediment Removal

> ➢ The goal of dredging technologies is to remove PCB-containing sediments for subsequent treatment or disposal.
>
> ➢ Sediment removal may not sufficiently reduce risks if, as at many other sites, dredging is unable to create a substantially cleaner sediment surface than before dredging began.

Four removal process options have been considered for submerged sediments of the Site. These include mechanical dredging, hydraulic dredging, dredging with specialized amphibious equipment, and mechanical excavation "in the dry." These process options were evaluated with respect to effectiveness, implement-ability, and cost in Table 3-3.

There are three types of dredges available for removing sediment including mechanical, hydraulic, and amphibious. Both hydraulic and mechanical dredges have a long successful history of removing sediment for navigational purposes. Each of these three dredge types is further discussed below including application, limitations, impacts, availability, and production rates.

Mechanical Dredges

A mechanical dredge uses direct force to dislodge and excavate the sediment. The most common mechanical dredge is the clamshell dredge due to its wide range of applicability. The clamshell bucket is often used in conjunction with a barge-mounted crane or from the shoreline. For environmental applications, a watertight clamshell bucket is used to minimize sediment resuspension associated with dredging. The watertight clamshell bucket allows for the flow of water through the bucket as it is lowered into the water column and has rubber gaskets or seals to prevent leakage of sediment from the bottom of the closed bucket as it is lifted up through the water column. Some watertight clamshell buckets are also designed to close at the bottom parallel with the water's surface leaving a flat surface following dredging. This design was developed to reduce the amount of overdredging that may be required to remove chemical-containing sediment. While generally insignificant for navigational dredging projects, overdredging can be an expensive component of an environmental dredging project given the cost associated with sediment handling and disposal.

Limitations for mechanical dredges include necessary water depth for barge-mounted applications and sufficient shoreline access for land-based applications. For environmental applications, dredge production rates are considerably lower than navigational dredging due to increased bucket cycle-time. The increased bucket cycle time is needed to minimize sediment resuspension and incorporate environmental controls and monitoring in the overall dredging process. Although a watertight clamshell is less disruptive to the environment as compared to a standard clamshell dredge, debris can prevent a watertight bucket from closing completely and increase sediment resuspension rates. Production rates for mechanical dredging range from 30 to 600 cy per hour. These rates are directly linked to the available water depth and the nature of the chemical-containing sediment and physical environment. While larger dredge buckets can often increase production, available water depth can be a limiting factor as the barge required to support such a dredge bucket typically requires a minimum draft of 5 to 6 feet.

Conventional clamshell dredges can be effectively used to remove a variety of debris. However, for situations with chemical-containing sediment, care must be taken to ensure that debris is removed without disturbing the sediment. This can require a separate debris removal operation using small equipment working from a shallow-draft barge.

Hydraulic Dredges

Hydraulic dredges use centrifugal pumps to remove the sediment in a slurry form. The dredge plant also transports the dredged material to a dewatering area or disposal facility through a pipeline. The dredge often includes a mechanical device (e.g., a cutterhead) at the point of dredging to loosen the sediment from the bottom and assist with debris. The common types of hydraulic dredges available include the cutterhead, dustpan, and bucket-wheel. To specifically address chemical-containing sediment, several variations of hydraulic dredges have been developed including the modified dustpan, clean-up, and matchbox dredges. Cutterhead dredges are the most common hydraulic dredges used in the United States today. They have been routinely used for environmental dredging projects due to their general availability, ability to operate in shallow water environments, and ability to minimize sediment resuspension as compared to other forms of dredging.

A limiting factor for hydraulic dredging is the large quantity of water generated during the dredging process. This challenge is greater for environmental dredging projects where the sediment slurry generally ranges from less than 1% to 10% solids. This is in contrast to navigation dredging operations that typically generate a dredged material slurry ranging from 10% to 20% solids. The large quantity of water generated often requires multiple treatment steps to achieve applicable water quality standards before release to the environment and can also be a limiting factor if the sediment must be dewatered prior to treatment and/or disposal. Hydraulic dredging does facilitate cost effective transportation of the dredged material as the slurry can be economically pumped long distances without having to rehandle the sediment. The use of a site-specific CDF in conjunction with hydraulic dredging can further minimize these limitations as it can be used for water treatment, dewatering, and sediment disposal.

Amphibious Dredging

Specialized amphibious dredges employ a combination of the hydraulic or mechanical dredging techniques discussed above to remove submerged sediments. The main advantage of using an amphibious dredge over more conventional full-scale mechanical or hydraulic dredges is that materials can be removed from more shallow, and therefore more difficult to access, areas of a site. Production rates from these types of specialty dredges are typically much lower than for conventional equipment, and their availability can be limited.

Mechanical Excavation "In the Dry"

Mechanical excavation "in the dry" commonly makes use of physical structures (e.g., portable dams, sheetpile walls) and pumps to maintain low water levels within the excavated area so that sediments are somewhat dewatered upon removal. Excavation in the dry is most feasible in shallow areas or near-shore environments where natural platforms exist for excavation equipment.

Although the relative costs for implementation of the sediment removal process options are expected to be high, and technical and administrative implementability issues may be significant, mechanical, hydraulic, and amphibious dredging are retained for potential incorporation into remedial alternatives. Mechanical excavation "in the dry" was not retained for assembly into remedial alternatives because it would be extremely difficult to implement on a large scale throughout the Site. An evaluation of dry excavation as it may apply to the Site is presented in Appendix E.

3.3.9 Dewatering

> - Dewatering technologies alone do not reduce risks, but they are necessary if sediment dredging technologies are employed.
> - By dewatering sediments pumped to shore by a dredge, the resulting solids are easier to handle and transport.

Four technology types and five respective process options are retained for dewatering of removed sediments. These process options include: plate and frame filter press, belt filter press, solid bowl centrifuge, evaporator, and hydrocyclone. Given the fine-grained nature of the majority of sediments in the current impoundments and downstream portions of the Site, significant dewatering/stabilization would be required prior to on- or off-site disposal of removed sediments. These process options were evaluated with respect to effectiveness, implementability, and cost in Table 3-3.

Plate and Frame Filter Press

A plate and frame filter press operation consists of a series of plates and frames held together using a hydraulic ram. Dredged material (which can be chemically conditioned to enhance filterability) are pumped into the space between the plates within the frames. Water is forced through filter media on the plates and out the plate outlets, which yields a dilute aqueous filtrate that may require further treatment. The dewatered solids are then removed by separating the plates and frames. An optional membrane filled with compressed air can be used to effect further dewatering.

Belt Filter Press

The belt filter press consists of two continuous belts, one above the other, between which dredged solids that previously have been gravity dewatered are fed. Pressure is applied to the belts to dewater the solids, yielding an aqueous filtrate that may require additional treatment. The dewatered solids are continuously removed from the belt by a scraper.

Solid Bowl Centrifuge

This process is widely used in industry to separate liquids of different density, thickening slurries, or removing solids. Chemicals may be added to dredged solids for conditioning prior to centrifuge operation. With this technology, solids are fed at a constant flow rate into the rotating bowl where they separate into a dense cake containing the solids and a dilute aqueous stream called "centrate" that may require further treatment. The solids cake typically is discharged from the bowl by a screw feeder.

Evaporator

This process option employs an evaporation unit into which previously gravity dewatered dredge solids are placed. The solids are subject to increased heat and pressure to vaporize water, which is collected separately for potential further treatment. The solids are then removed and appropriately disposed.

Hydrocyclone

In the operation of hydrocyclones, slurry is fed into a spinning, funnel-shaped cyclone separator. Centrifugal force acting on the solids retains solid particles to the outer wall of the separator. These solids fall by gravity to the bottom of the separator for removal. Water effluent or overflow migrates toward the center of the unit, spirals upwards through a centrally-located pipe, and out the top of the cyclone.

3.3.10 Disposal

> - Disposal facilities are needed in conjunction with removal technologies to store and isolate waste materials from the environment.
> - Options include large "confined disposal facilities" that would need to be constructed within the river basin or on nearby lands, or the use of existing solid waste and hazardous waste landfills.

Technologies for the disposal of sediment solids are considered in conjunction with sediment removal and residuals management response actions. The process options being considered for sediment disposal are construction of one or more new landfills or confined disposal facilities (CDFs) near the Site and the use of existing, permitted solid waste and Toxic Substances Control Act (TSCA)-permitted landfills. These process options can be applied either to treated or untreated sediments. Each of these process options is discussed below, and evaluated with respect to effectiveness, implementability, and cost in Table 3-3.

Confined Disposal Facilities

CDFs would be constructed to accommodate sediment removed from the river channel to permanently isolate PCB-containing dredged material from the environment. These facilities would be constructed within the river basin or in upland areas adjacent to the river at locations selected to receive dredged materials from as wide a segment of the river as needed, while transporting the material over as short a distance as practical. These facilities are designed to allow sediment solids to gravitationally separate, settle, and consolidate as decanted water is then directed to a treatment system. The CDFs may be required to operate over an extended length of time, depending on the period required for sediment removal. After operation, the CDFs would be capped with an appropriate landfill cover.

Solid Waste Landfills

This process option would involve the disposal of sediment to an existing off-site permitted solid waste landfill. Dewatering of the sediments would likely be necessary prior to disposal to meet landfill requirements. This process option would not be used for sediments containing PCB at concentrations of 50 mg/kg or greater.

TSCA Landfills

Sediments containing PCB at concentrations of 50 mg/kg or greater may be required to be disposed in a TSCA-regulated landfill. A TSCA landfill with limited available capacity currently is in operation within the metropolitan area of Detroit, Michigan.

3.3.11 Residuals Management

> ➢ **To the extent remedial actions (such as dredging) generate residual wastes during sediment dewatering and water processing, these materials must be treated or otherwise managed to prevent release to the environment.**

Residuals management, as the conventional term of feasibility studies (apart from the term used to identify certain papermaking wastes), applies to process water and other materials from dewatering of submerged sediment. The representative process options retained for managing water created through residuals management are in-line filtration (i.e., sand filter) and carbon adsorption. These process options are discussed below, and were evaluated with respect to effectiveness, implementability, and cost in Table 3-3.

In-Line Filtration

Since PCB are highly hydrophobic and relatively insoluble, they are expected to be associated primarily with suspended particulates rather than dissolved in the process water. Therefore, filtration is expected to be effective in removing PCB from process water.

Activated Carbon Adsorption

Activated carbon is retained as a means of removing potential dissolved PCB in the filtered water as a polishing step following filtration. These processes, in turn, generate spent carbon and filtered solids that can be managed by appropriate landfill disposal.

3.3.12 Fisheries Management

> - Several physical and chemical means are available to remove or modify the fishery within an aquatic system to reduce exposure through fish consumption.
> - These techniques are not considered further because of their limited effectiveness in a river as large as the Kalamazoo.

Several fish harvesting techniques are available as process options with the goal of reducing potential exposure of anglers to PCB via fish consumption. This could be done by: 1) reducing the overall availability of species consumed by anglers; or 2) when followed either by natural or active restocking of the fishery over a number of years, reducing the abundance of fish species that accumulate relatively high PCB concentrations while increasing the abundance of species that accumulate comparatively low concentrations of PCB. A secondary outcome of fish harvesting is the removal of a small percentage of the accumulated PCB mass in resident fish from the aquatic ecosystem.

Specific process options range from gill or trap netting to electrofishing to chemical treatment. Netting and electrofishing techniques have the advantage of being relatively selective in harvesting target species, but the disadvantage of being ineffective in removing large numbers of fish from an area as large as the Site. While chemical treatment with a piscicide (fish poison) such as rotenone can result in high mortality of fish, it is non-selective in killing fish species and is not a proven technique at the necessary scale. Moreover, it would likely be difficult to gain permitting and public approval for use of chemical treatment in light of the obvious additional negative impacts from rapid death and decay of approximately 90,000 pounds of fish (assumes 500 pounds per acre), the loss of the entire fishery until recovered or restocked, and the potential for uncontrolled downstream fish kills. Due to the ineffectiveness of netting and electrofishing, and the technical and administrative limitations of chemical treatment, fish harvesting on this scale is not retained for further evaluation within this FS. The evaluation of the Fisheries Management GRA with respect to effectiveness, implementability, and cost is presented in Table 3-3.

3.4 Assembly of Potential Remedial Alternatives

> - By combining the 11 different types of technology and 25 specific process options, a total of five remedial alternatives are assembled for evaluation in Sections 4 and 5.
> - The alternatives range from "no further action" to river-wide capping or removal of submerged sediments, with source control, monitored natural attenuation, and institutional controls all important additional components.

Based on the screening described above, specific technologies and process options were assembled into five alternatives for remediation of the Site. These remedial alternatives are briefly described below.

In assembling the remedial alternatives, a number of representative process options were included to develop a range of various potential remedial alternatives to address RROs for the Kalamazoo River.

Alternative 1 - No Further Action

The no further action alternative is presented because it is required by the NCP. No active remediation would be performed in any area of the Kalamazoo River. Natural attenuation processes would continue but would not be gauged since no monitoring would be performed.

Alternative 2 - Institutional Controls and Monitoring

As noted previously, substantial remedial efforts have been undertaken at the Site in the form of OU remediation and other source control measures. For such actions, the NCP states that "one or more alternatives that involve little or no treatment, but provide protection of human health and the environment primarily by preventing or controlling exposure to hazardous substances through engineering controls" shall be developed. Examples of such alternatives include containment and institutional controls. Alternative 2 includes the following:

- Continuation of fish consumption advisories to be protective of human health;
- Ongoing natural attenuation processes that include burying of PCB-containing sediment through natural deposition of cleaner material; and
- Long-term monitoring to determine when fish consumption advisories may be relaxed or eliminated.

The success of this alternative is premised on the assumption that dams at the current impoundments and sills at the former impoundments would be periodically inspected, maintained, and operated by their respective owners, consistent with statutory requirements.

Alternative 3 - Bank Stabilization at the Former Impoundments, Monitored Natural Attenuation, and Institutional Controls

This alternative includes the basic components of Alternative 2, which includes institutional controls and in-place containment through natural processes. However, Alternative 3 adds the process option of engineered bank stabilization in the former impoundments. This measure is intended to mitigate sloughing of exposed sediment into the Kalamazoo

River, which the RI determined is the single largest ongoing source of PCB to the river system. Also added is monitoring to confirm that the mechanisms of natural attenuation processes at the Site are reducing exposure to PCB at expected rates, and investigation and monitoring of potential external PCB-sources, including certain tributaries, publicly owned treatment works (POTWs), industrial stormwater, effluents, storm sewer effluents, and various other runoff sources. Depending on the findings of that work, additional responses to address these sources beyond this alternative may be appropriate.

Alternative 4 - River-Wide Capping of Submerged Sediments, Bank Stabilization at the Former Impoundments, Institutional Controls, and Monitoring

This alternative includes engineered containment through the placement of clean sediment materials such as sand and gravel over all submerged sediments in the Kalamazoo River from Morrow Dam to Lake Allegan Dam. The bank stabilization and monitoring program identified in Alternative 3 would also be included in this alternative. Placement of an engineered cap over the submerged Site sediments broadens the spectrum of potential remedial alternatives being considered, allowing a direct comparison of containment-based remediation with the removal-based approach of Alternative 5.

Alternative 5 - River-Wide Dredging of Submerged Sediments with Upland Confined Disposal, Bank Stabilization at the Former Impoundments, Institutional Controls, and Monitoring

This alternative will address the removal of all submerged sediments from the Kalamazoo River system that contain PCB, as described in Section 2-5. The bank stabilization and monitoring program identified in Alternative 3 would also be included in this alternative. The location of potential access points for placement of hydraulic dredging equipment into the Kalamazoo River and impoundments will be identified, the amount of grubbing and clearing of bank areas that must be performed to allow such access will be determined, and the size and locations for water treatment facilities will be determined. In addition, a series of upland CDFs will be sized to contain all of the dredged materials generated by this alternative, and potential candidate sites for the CDFs in the Kalamazoo and Allegan County communities will be identified. This alternative will allow for the estimation of the costs and effectiveness of a remedial project that attempts to remove the total PCB-impacted sediment mass from the Kalamazoo system.

3.5 Screening of Potential Remedial Alternatives

Assembled alternatives are typically screened on the bases of implementability, effectiveness, and cost to reasonably limit the number of alternatives undergoing detailed analysis. This step is performed when an unmanageable number of alternatives are assembled due to the availability of a large number of GRAs and remedial technologies. In this case, the screening of alternatives has not been performed for the five alternatives assembled above because this number was deemed manageable for detailed evaluation. All five alternatives were retained for detailed evaluation.

- USEPA guidance for conducting feasibility studies allows for an additional screening step to narrow the number of remedial alternatives to be evaluated in detail.
- This step is not necessary for this Site because five is a reasonable number of alternatives to evaluate, and all major types of remedial technology are represented.

In response to a request by the MDEQ that an alternative including dam removal be developed and evaluated, Appendix F discusses the scope, implementation considerations, and costs of removing the three former dam structures and associated sediments at the former Plainwell, Otsego, and Trowbridge impoundments. Since the removal of these structures is not necessary to the achievement of the RROs for the Site, and is not otherwise required under the NCP, dam removal is not developed as an alternative for comparative analysis within the body of the FS.

Inside Section 4 – Detailed Evaluation of Remedial Alternatives

Each of the five alternatives developed in Section 3 is evaluated against nine CERCLA criteria; the results of each evaluation are then compared to one another in Section 5.

The CERCLA criteria are:

- *Overall Protection of Human Health and the Environment* – Does the alternative achieve and maintain protectiveness? Is exposure to PCB reduced? Are all the remedial response objectives met?
- *Compliance with Applicable or Relevant and Appropriate Requirements* – Does the alternative comply with all ARARs, or are waivers necessary?
- *Long-Term Effectiveness and Permanence* – Does the alternative maintain protection of human health and the environment after response objectives have been met?
- *Reduction of Toxicity, Mobility, or Volume through Treatment* – Does the alternative reduce the mobility, toxicity, or volume of PCB through treatment?
- *Short-Term Effectiveness* – How does the alternative affect human health and the environment during implementation?
- *Implementability* – Is the alternative technically and administratively feasible? Are trained workers and necessary equipment and materials readily available? How long will the project take?
- *Cost* – Is the cost to implement the alternative justified by the level of risk reduction?
- *Agency Acceptance* – To what extent is the alternative acceptable to state and federal agencies?
- *Community Acceptance* – What concerns do local residents and other stakeholders have about the alternative?

The five remedial alternatives are:

- *Alternative 1 – No Further Action.* Relies on ongoing natural attenuation as well as source control and other actions already taken. Implemented immediately. No cost.
- *Alternative 2 – Institutional Controls and Monitoring.* Fish consumption advisories in effect, dam or sill heights at impoundments maintained, and fish sampling and analysis program implemented. Implemented immediately. Cost: $1.2 million.
- *Alternative 3 – Bank Stabilization at the Former Impoundments, Monitored Natural Attenuation, and Institutional Controls.* Adds erosion control and bank stabilization in the former impoundments to the elements of Alternative 2, expands monitoring program. Construction would take four years. Cost: $73 million.
- *Alternative 4 – River-Wide Capping of Submerged Sediments, Bank Stabilization at the Former Impoundments, Institutional Controls, and Monitoring.* Includes all the elements in Alternative 3, adds the capping of all 2,895 acres of river and impoundment sediments. Construction would take 40 years. Cost: $1.7 billion.
- *Alternative 5 – River-Wide Dredging of Submerged Sediments with Upland Confined Disposal, Bank Stabilization at the Former Impoundments, Institutional Controls, and Monitoring.* Includes all elements of Alternative 3, adds the removal of 16,000,000 cubic yards of sediment from the river. All sediment removed goes into three landfill areas built along the river. Construction would take 25 years. Cost: $2.6 billion.

4. Detailed Evaluation of Remedial Alternatives

4.1 Overview

> - In this section, the five alternatives assembled in Section 3 are each described in detail and then individually evaluated with respect to the nine criteria required by the NCP and USEPA guidance.
> - The nine criteria used to evaluate each alternative are:
>   - Overall protection of human health and the environment
>   - Compliance with ARARs
>   - Long-term effectiveness and permanence
>   - Reduction of toxicity, mobility, or volume through treatment
>   - Short-term effectiveness
>   - Implementability
>   - Cost
>   - Agency acceptance
>   - Community acceptance

In accordance with the NCP, this section describes the detailed evaluation of the remedial alternatives developed for the Site. Each alternative is assessed with respect to the NCP evaluation criteria described below. The results of this detailed evaluation are then compared in Section 5 in terms of each criterion and key tradeoffs among the various alternatives.

The detailed evaluation of remedial alternatives consists of a description of each alternative followed by an evaluation relative to each individual criterion described below. Preliminary cost estimates for each alternative also have been developed and are included. Note that proposed equipment and processes described are subject to modification during the design phase, and preliminary time frames are subject to refinement following the collection of detailed design information.

4.2 CERCLA Evaluation Criteria

The NCP and CERCLA require that remedial alternatives be evaluated with respect to nine criteria in order to select the most appropriate remedial alternative. The nine CERCLA evaluation criteria are as follows:

1. **Overall Protection of Human Health and the Environment** - This criterion addresses the overall effectiveness of an alternative in protecting human health and the environment by reducing potential exposure to achieve the identified RROs.

2. **Compliance with ARARs** - This criterion assesses whether a given alternative would comply with chemical-specific, location-specific, and action-specific ARARs, as well as other appropriate criteria, advisories, and guidance.

3. **Long-Term Effectiveness and Permanence** - This criterion considers the effectiveness of a given alternative with respect to reducing exposure and potential risk and the ability to maintain protectiveness over time.

4. **Reduction of Toxicity, Mobility, or Volume Through Treatment** - This criterion considers expected reductions in toxicity, mobility, or volume of chemical-containing materials through treatment as a result of implementing an alternative.

5. **Short-Term Effectiveness** - This criterion considers short-term adverse impacts to human health and the environment related to construction and implementation of the remedial alternative. Considerations include short-term environmental impacts of construction, the protection of on-site workers and the neighboring community, and the time until remedial response objectives are achieved.

6. **Implementability** - This criterion evaluates the implementability of an alternative with respect to both technical and administrative feasibility, including the availability of appropriate services and materials. Technical feasibility includes the ability to construct and operate the technology, the reliability of the technology, and the ability to effectively monitor the technology. Administrative feasibility includes the ability to obtain any applicable permits, and the degree to which any coordination with other government agencies can be achieved.

7. **Cost** - The cost criterion evaluates capital, operation and maintenance (O&M), and present worth costs of implementing an alternative. Present worth costs, where appropriate, are developed using a discount rate of 7% based on OSWER Directive No. 9355.3-20 (USEPA, 1993). In consideration of engineering and construction contingencies, these feasibility-level costs are typically estimated with an accuracy in the range of +50% to -30%.

8. **Agency Acceptance** - This criterion addresses the technical and administrative issues that the non-lead regulatory agency may have regarding each alternative (in this case the MDEQ is the lead agency, with the USEPA providing technical and other support). This criterion is typically evaluated following comment on the RI/FS reports and the Proposed Plan. It will be addressed once a final decision is being made and the Record of Decision (ROD) is being prepared.

9. **Community Acceptance** - The community acceptance criterion evaluates issues and concerns that the public may have with the selected alternative following public comment on the Proposed Plan. It will be addressed before a final decision is made, and agency responses to public comments will be provided in the ROD's Responsiveness Summary.

4.3 Application of Fate and Transport Model for the Kalamazoo River

The purpose of the detailed evaluation of alternatives is to provide a discussion of how each remedial alternative will address each of the nine NCP criteria. The development and application of mathematical models of PCB fate, transport, and bioaccumulation for this purpose has become a standard part of the RI/FS evaluation of large PCB-contaminated aquatic sites, and was anticipated by the RI/FS Work Plan for this Site. Such a model *has been under development for the Kalamazoo River and is reported in the Supplement* to the Kalamazoo River RI/FS. However, at the direction of the MDEQ, which has not yet reviewed this model, it is not used in this RI/FS. Section 2.5 discusses the application of simple calculations to determine the effects of hypothetically perfect sediment remediation in Lake Allegan.

4.4 Alternative 1 - No Further Action

Description

Alternative 1 is required by the NCP and serves as a baseline against which the other remedial alternatives are evaluated. Because certain remedial activities have previously been implemented at the Site (e.g., remediation of the OUs; see Section 1.5), this no further action alternative does not include any additional remedial activities beyond those that have already taken place. In addition, it assumes that the fish consumption advisories would no longer be maintained.

> - **Natural recovery processes are evident in Kalamazoo River fish, surface water, and surface sediment. Levels of PCB throughout the system are markedly lower today than they were at their peak in the 1970s.**
> - **Natural attenuation (also known as natural recovery) is the primary component of Alternative 1; it is the baseline against which other potential remedies are evaluated.**

Alternative 1 includes and considers the natural attenuation processes at work in the system that have been reducing potential exposure to PCB over time. Evidence of active natural attenuation processes at the Site was empirically identified through data compiled during the RI, including statistical analyses of those data and historical (e.g., mid-1980s) data. Understanding those processes and additional evidence occurred during the development and application of the Kalamazoo River PCB Simulation Model (KALSIM) fate and transport model, described in the *Supplement to the Kalamazoo River RI/FS*.

As introduced in Section 3.3, natural attenuation in sediments occurs through physical, chemical, or biological processes that are inherent and active, to varying degrees, within all aquatic systems. At this Site, the primary attenuation mechanism is the physical process of surface sediments containing potentially bioavailable PCB mixing with new solids delivered from the watershed. As this process continues over time, sorting and resedimentation occurs in low energy areas, the surface sediments are gradually buried deeper in the sediment bed of those areas, and each new surficial mixing layer becomes progressively cleaner over time.

Natural attenuation in the Kalamazoo River is demonstrated through several lines of empirical evidence found in fish, water, and sediment data. As PCB bioavailability and exposure potential have decreased over the past two decades or more, fish within the system have responded with corresponding downward trends in PCB concentrations. Given that the primary RRO for the Site is the reduction of PCB levels in fish, the rates of change in fish PCB levels are of particular interest. Similarly, PCB trends in surface sediments (i.e., the bioavailable zone) and the water column also are of interest because these media play an important role in PCB availability and potential exposure of fish and, via the food chain, the human or ecological consumers of those fish. The trends in these media are presented and discussed in detail in the RI Report.

Based on RI sampling and MDNR historical monitoring, the most comprehensive fish data sets are for smallmouth bass and carp, including data from 1985, 1993, and 1997 at Morrow Lake, the former Plainwell Impoundment, and Lake Allegan. Additional data were collected and analyzed in 1999, and are reported in the *Supplement to the Kalamazoo River RI/FS*. One method of estimating rates of natural attenuation is to use linear regression analyses to estimate rates of change in terms of "half time," which is the time period needed for PCB concentrations to decrease by half. Based on the half times for wet-weight PCB levels in smallmouth bass (<16") fillets and carp (<22") fillets, PCB concentrations are dropping steadily, with half times ranging from 3.2 years to 4.5 years for smallmouth bass and from 6.2 years to 11 years for carp. To take into account the non-temporal factors that may be influencing observed trends in fish (e.g., lipid content), data for both species were also analyzed using multi-variate regression analysis which showed that the rate of PCB concentration decrease at the former Plainwell Impoundment is approximated by a 14-year half time and by a 6.5-year half time for Lake Allegan. These estimated rates of decrease are likely slower than would otherwise be expected as uncontrolled upstream sources and erosion of the bank deposits in the former impoundments continue to transport PCB to the river, the cessation of which would likely speed the effects of natural attenuation.

Similar evidence of natural attenuation can be observed in surface water and sediment data. PCB concentrations in surface water from the mid-1980s, 1994, and 1999 (analyzed in the RI Report [BBL, 2000b]) showed, based on regression analyses, an overall half time of 4.6 years for all locations from Plainwell downstream. This represents a significant reduction in the PCB load carried by the water column since the mid-1980s. Based on 1994 surface water data and the five methods of estimation described in the RI Report (BBL, 2000b), PCB loading at the M-89 sampling station downstream of Lake Allegan near Fennville was approximately 25 kilograms per year (kg/yr), which is significantly less than historical maximums. These reductions in surface water concentrations and loading are direct evidence of the effectiveness natural attenuation and the decreasing availability of PCB for biological exposure and advective transport within the Kalamazoo River.

RI data including geochronologic dating of sediment cores[1] confirms two things: 1) PCB bioavailability in surface sediments has decreased significantly since the 1970s, and 2) the impoundments, especially Lake Allegan, are efficient sediment traps and highly depositional in nature. The estimated rate of sedimentation is approximately 0.5 centimeters per year (cm/yr) in the Allegan City Impoundment. Data for Lake Allegan are provided in the *Supplement to the Kalamazoo River RI/FS*).

Overall Protection of Human Health and the Environment – Alternative 1

> ➢ Natural attenuation processes could achieve RROs 1 and 2 through the continued decreases in PCB bioavailability and exposure over time, which would reduce PCB concentrations in fish and provide adequate protectiveness in the long term. Similarly, natural attenuation would decrease the availability of PCB for downstream transport.

PCB concentration in fish is the key determinant of an alternative's overall effectiveness and level of protectiveness of human health and the environment. Under Alternative 1, the natural attenuation processes discussed above and in the RI report could achieve RROs 1 and 2 through the continued decreases in PCB bioavailability and exposure over time, if external loading of PCB to the system diminishes progressively. In that case these processes would reduce PCB concentrations in fish and provide adequate protectiveness in the long term. Similarly, natural attenuation would decrease the availability of PCB for downstream transport.

The absence of fish consumption advisories could potentially increase consumption and, therefore, could increase risk in the short term. However, the 1993 and 1997 fish data indicate that there have been measured decreases in fish tissue PCB concentrations since at least the mid-1980s (refer to the RI Report [BBL, 2000b] for detailed discussion and the *Supplement to the Kalamazoo River RI/FS* for an update based on 1999 data). These same decreases in fish tissue content would suggest that exposure is decreasing as well for those human and ecological receptors consuming fish from the Kalamazoo River. Empirical estimates of rates of decrease of fish tissue PCB levels indicate half times on the order of 4 to 10 years for smallmouth bass and carp. Estimates of decreased water column PCB concentrations over time (e.g., an estimated 75% less in 1999/2000 as compared to the mid-1980s based on average concentrations at Plainwell) will reduce PCB availability for exposure and transport. Thus, Alternative 1 is expected to achieve RROs 1 and 2.

[1] The Kalamazoo River is dominated by the presence of seven existing or former (now partially) impounded water bodies where solids are actively deposited and retained behind dams and within the associated basins. Taken together, these basins cover approximately 2,100 acres (3,100 if you include Morrow Lake), which constitutes the great majority of the entire river's surface area.

As with all other alternatives evaluated in this FS Report, the overall protectiveness of Alternative 1 will likely be limited by the continuing inputs of PCB to the Site from upstream and other known or potential uncontrolled sources. The sloughing of the banks of the former sediments in the three MDNR-owned former impoundments represents an ongoing source of PCB transport to the river that will act to slow rates of recovery. Other potential sources that would not be further investigated and/or addressed under Alternative 1 include certain tributaries, POTWs, industrial storm water effluents, and storm sewer effluents.

Compliance with ARARs – Alternative 1

Since no active remedial efforts are proposed under Alternative 1, action- and location-specific ARARs do not apply. With regard to chemical-specific ARARs, Alternative 1 would not be expected to achieve the Michigan Part 31 PCB Water Quality Standard (MDEQ, 2000) for protection of human health (0.000026 μg/L) or the standard for protection of wildlife (0.00012 μg/L) that were developed to meet Rule 323.1057. This is true for all reaches of the river, including Morrow Lake, due to continued loading from uncontrolled sources upstream of the Site and from erosion of the former impoundment banks. These ARARs would have to be waived to facilitate implementation of Alternative 1.

> ➢ Michigan water quality standards related to protection of human health and wildlife would have to be waived for the entire river, even upstream of the Site. Such a waiver would be necessary under all five alternatives.

Long-Term Effectiveness and Permanence – Alternative 1

Effectiveness is directly related to the degree of risk reduction achieved through implementation of an alternative, as indicated by an alternative's effects on PCB levels in fish. As discussed in the description of Alternative 1 and the evaluation for overall protectiveness, the long-term effectiveness of this alternative is based on the risk reduction achieved through observed and ongoing natural attenuation of PCB concentrations in fish, as well as in surface sediment and the water column. RI data analyses indicate that fish PCB levels have been declining since at least the mid-1980s, and are expected to continue to decline (the most recent data suggest that current fish consumption advisories could be substantially relaxed). However, this no further action alternative assumes that advisories would no longer be in place, which could potentially increase human consumption and exposure. Nevertheless, both human and ecological exposure would be expected to decrease over the long term as fish tissue concentrations continue to decrease along observed trends. Similarly, PCB transport would be expected to decrease, but at a rate slowed by continued loading from upstream and former

> ➢ The long-term effectiveness of Alternative 1 is based on the risk reduction achieved through observed and ongoing natural attenuation of PCB concentrations in fish, surface sediment, and the water column. RI data analyses indicate that fish PCB levels have been declining since at least the mid-1980s, and are expected to continue to decline.

impoundment bank source areas. Monitoring is not proposed under Alternative 1, so the effectiveness of natural attenuation processes could not be measured or evaluated over time.

Reduction of Toxicity, Mobility, or Volume Through Treatment – Alternative 1

No active treatment is proposed under Alternative 1. Therefore, no reduction in potential toxicity, mobility, or volume would occur through treatment. However, the physical natural attenuation process of sedimentation, mixing, and burial is expected to continue to remove PCB from bioavailable surface sediments, thus decreasing mobility and making them unavailable for biological exposure and downstream transport. As discussed in the description of this alternative, the Kalamazoo River is dominated by impounded areas that are conducive to these processes. Empirical observations show that PCB availability is declining within the Site as a continuation of the marked decline observed since the 1970s and 1980s. PCB toxicity and concentration is expected to be reduced to a limited extent over time through natural dechlorination.

Short-Term Effectiveness – Alternative 1

Since no active remedial measures are proposed as part of Alternative 1, no short-term adverse impacts to human health and the environment are associated with implementation of this alternative. However, the absence of fish consumption advisories could potentially increase consumption and, therefore, could increase short-term risk.

Implementability – Alternative 1

This alternative poses no technical or administrative implementability concerns since no further action would be taken. No equipment or specialized services would be required to implement this alternative, and no specific approvals or permits would be necessary.

Cost – Alternative 1

No capital or O&M costs are associated with implementation of Alternative 1.

4.5 Alternative 2 - Institutional Controls and Monitoring

Description

> - Alternative 2 adds institutional controls (fish consumption advisories and maintenance of sill heights at the former impoundments) to the natural recovery component of Alternative 1.
> - A monitoring component is also included – long-term tracking of the progress of natural attenuation in fish, water, and sediment will monitor the continuation of improvements seen in the river over the last 25 years.

Alternative 2 would include the ongoing natural attenuation processes discussed under Alternative 1 together with the implementation of institutional controls and Site monitoring as part of a comprehensive remedy. Institutional controls would include maintaining current sill and dam heights at former impoundments by the MDNR and at current impoundments by their owners, maintenance and updates of fish-consumption advisories by the MDCH based on monitoring data, and implementation of a periodic fish sampling and analysis program. This alternative also includes investigation and monitoring of potential external PCB sources, including certain tributaries, POTWs, industrial stormwater effluents, storm sewer effluents, and various other runoff sources. Depending on the findings of that work, additional responses beyond this alternative may be appropriate.

Long-term monitoring under Alternative 2 would be conducted to document the progress of natural attenuation in the Kalamazoo River and to assess the need for continued institutional controls such as consumption advisories. Fish monitoring activities currently are underway and, therefore, would be easily implemented. Fish monitoring activities targeting carp and smallmouth bass would involve two approaches: adult fish sampling to assess applicable fish consumption advisories, and yearling fish sampling to assess trends in bioavailable PCB. Adult fish would be processed as skin-on fillets according to Michigan Fish Advisory guidelines (Michigan Environmental Science Board, 1998; MDEQ, 1999; GLSFATF, 1993) to obtain samples that are representative of standard edible portions to assess appropriate fish consumption advisories. Natural attenuation trend monitoring would require sampling of yearling fish, which have lower variations in PCB concentration than adult fish and, therefore, can be used to statistically determine bioavailability over relatively short periods of time. The yearling fish would be analyzed as whole-body composite samples. All samples would be analyzed to measure PCB concentration and percent lipid.

Other analyses to be conducted to assess the progress of natural attenuation under this alternative would include surface water sampling for PCB, and surface sediment sampling for PCB, TOC, particle size, bulk density, and specific gravity. All monitoring would be conducted in accordance with the existing approved *Field Sampling Plan* (FSP; BBEPC, 1993d), *Health and Safety Plan* (HASP; BBEPC, 1993b), and *Quality Assurance Project Plan* (QAPP; BBEPC, 1993a). Specific work plans would be developed prior to commencement of each sampling event, with results presented and discussed in a brief report compiled after each monitoring period. Additional details of this monitoring program are provided in Table 4-2 (note that monitoring would continue indefinitely or until no longer necessary; for cost estimating purposes a 30-year program is assumed).

Overall Protection of Human Health and the Environment – Alternative 2

> ➢ Natural recovery processes would decrease PCB exposure and transport over time, which would reduce PCB concentrations in fish in the long term and thus achieve RROs 1 and 2. Use of institutional controls will also help reduce PCB exposure and transport.

In considering the overall protectiveness of any remedial alternative, the PCB concentrations in fish are the key determinant of an alternative's effectiveness and ability to protect human health and the environment. Although no active remediation would be implemented under Alternative 2, the natural attenuation processes discussed under Alternative 1 would decrease PCB bioavailability and exposure over time, which would reduce PCB concentrations in fish in the long term. Similarly, natural attenuation would decrease the availability of PCB for downstream transport.

Alternative 2 makes additional provision for protection of human health through implementation of institutional controls by proposing that the MDCH maintain and modify, as appropriate, fish consumption advisories to reflect the latest monitoring data collected during the RI. Monitoring would provide a means of tracking PCB concentrations in fish and other media to monitor potential exposure concentrations and pathways for key ecological receptors that may be at risk. Continued operation of the Morrow Dam, Allegan City Dam, and Lake Allegan Dam to minimize the release of sediments and PCB in the bed of the associated impoundments will foster the continued deposition of progressively cleaner sediment. These combined actions are expected to reduce PCB availability for exposure and transport and, therefore, achieve RROs 1 and 2.

As with all other alternatives evaluated in this FS, the overall protectiveness of Alternative 2 will likely be limited by the continuing inputs of PCB to the Site from upstream and other known or potential uncontrolled sources. The sloughing of the banks of the former sediments in the three former impoundments would remain a significant additional ongoing source of PCB transport to the river that would act to slow rates of recovery that would otherwise be expected in the absence of these continuing uncontrolled sources.

Compliance with ARARs – Alternative 2

Since no active remedial activities are proposed under Alternative 1, action- and location-specific ARARs do not apply (USEPA, 1988). As discussed previously under Alternative 1, Alternative 2 would not be expected to achieve the Michigan Part 31 PCB Water Quality Standard for protection of human health (0.000026 µg/L) or the wildlife (0.00012 µg/L). This is true for all reaches of the river, including upstream in Morrow Lake, due to continued loading from uncontrolled sources upstream of the Site and from erosion of the former impoundment banks. These ARARs would have to be waived to facilitate implementation of Alternative 2.

Long-Term Effectiveness and Permanence – Alternative 2

Effectiveness is directly related to the degree of risk reduction achieved through implementation of an alternative, as indicated by an alternative's effects on PCB levels in fish. As discussed in the description of Alternative 2 and the evaluation for overall protectiveness, the long-term effectiveness of this alternative is primarily based on the risk reduction achieved through observed and ongoing natural attenuation of PCB concentrations in fish, as well as in surface sediment and the water column. RI data analyses indicate that fish PCB levels have been declining since at least the mid-1980s to the point where the 1993 and 1997 data justify evaluation by the MDCH to substantially reduce current fish consumption advisories.

Maintenance of the impoundments at their present pool elevations by the MDNR and other dam owners would ensure that the PCB-containing sediments retained behind the dams and within the impoundments would be permanently confined to these areas and not be released or mobilized for downstream transport. Maintenance of sill elevations would also facilitate continued attenuation of PCB to reduce bioavailable concentrations in surface sediments. To the extent the proposed additional source investigation and control actions by the MDEQ were effective, present rates of natural attenuation would be expected to continue or increase over the long term. Finally, Alternative 2 includes a long-term monitoring component that would track the effectiveness and permanence of the actions taken under this alternative.

Reduction of Toxicity, Mobility, or Volume Through Treatment – Alternative 2

Since no active treatment is proposed under Alternative 2, no reduction in potential toxicity, mobility, or volume would occur through treatment. However, as previously stated, reduction in toxicity and volume are expected to occur to a limited extent as a result of natural dechlorination. PCB mobility in the sediment bed would decrease in depositional environments through continuing physical processes of mixing, sedimentation, and burial.

Short-Term Effectiveness – Alternative 2

> ➢ Unlike other alternatives, Alternative 2 could be started immediately and would cause no disruption of the environment or use of the river.

Alternative 2 includes a combination of natural attenuation, institutional controls, and monitoring, including sampling and analysis of biota at the Site. Monitoring activities would be performed in accordance with project-specific HASPs. Therefore, adverse short-term impacts on human health and the environment would be mitigated during implementation of this alternative. There would be no mechanical processes that would potentially disrupt the ecological features of the Site.

Each of the actions under Alternative 2 could be implemented immediately or in the very near term to improve the short-term effectiveness of the alternative. For example, the MDCH could initiate a comprehensive review of current (2000) (MDCH, 2000) and proposed (2001) (BBL, 2000c) fish consumption advisories based on monitoring data already collected and reported in the RI Report (up to 1997) and the *Supplement to the Kalamazoo River RI/FS* (including new data from 1999). Secondly, the MDNR could immediately take action to stabilize and potentially rehabilitate its three impoundment dam sills and spillways based on the "high hazard" ratings its dams received after safety inspections in 1995 (Hayes, 1995b; 1995c; 1995d), 1996 (Hayes, 1996a, 1996b, 1996c), and 1999 (CDM, 1999a; 1999b; 1999c). Finally, although the RI included considerable effort to identify all known or potential sources of PCB to the Site, the RI data clearly indicate the presence of ongoing sources upstream of and within the Site. These sources are not related to the KRSG source areas that have already been controlled or are undergoing necessary response actions under separate work plans and decision documents. Accordingly, Alternative 2 proposes that additional actions be taken by the MDEQ to identify and mitigate these sources.

Implementability – Alternative 2

> ➢ No technical or administrative issues would hamper the implementation of Alternative 2.

This alternative poses no technical implementability concerns. The personnel and equipment needed to periodically collect and analyze fish, surface water, and sediment samples from the Site are readily available. Posting of fish consumption advisories and implementation of a fish tissue monitoring program are generally accepted practices for controlling potential risks through human consumption.

No specialized labor or equipment is anticipated to maintain the existing dam structures or pool elevations, or to address any external PCB sources, should they be identified. However, to properly implement these activities, cooperation and approval by the MDNR, MDEQ, and the property owners/pertinent responsible parties would be necessary. Despite statutory obligations to do so, administrative implementability concerns relate to the willingness of dam owners to conform with the law and perform periodic inspection and monitoring, and the MDNR and MDEQ to undertake dam maintenance and additional source control actions, respectively.

Cost – Alternative 2

The estimated capital and O&M costs to implement Alternative 2 are approximately $0 and $1,186,000, respectively, for a total cost of $1,186,000 (+50%/-30%). This results in an overall estimated present worth cost of approximately $653,000 over 30 years. A breakdown of the estimated costs for implementing Alternative 2 is presented in Table 4-2. Note that these costs do not include actions that would be taken by other parties such as additional source investigations, state- or privately-owned dam maintenance, or MDCH data analyses.

4.6 Alternative 3 - Bank Stabilization at the Former Impoundments, Monitored Natural Attenuation, and Institutional Controls

> - Alternative 3 aims to address the most significant identified ongoing source of PCB to the river by stabilizing the riverbanks in the three former impoundments. This will prevent future erosion and slumping of PCB into the river.
> - Alternative 3 builds on Alternative 2 by adding bank stabilization/source control and a significantly expanded long-term monitoring program to closely track the progress of natural recovery.

Alternative 3 includes the components discussed under Alternative 2 (i.e., natural attenuation, institutional controls, and monitoring) together with erosion control/bank stabilization measures along the banks of the former impoundments. The remedial components of Alternative 2 are discussed in Section 4.5. Therefore, a description of the bank stabilization activities and expanded monitoring program is provided in this section followed by a detailed evaluation with respect to the NCP evaluation criteria cited in Section 4.2.

As discussed earlier, the Kalamazoo River was impounded by a series of dams around the turn of the century, three of which formed the Plainwell, Otsego, and Trowbridge impoundments. In the early 1970s, the water levels behind these three dams were rapidly, and then permanently, drawn down. In 1987, the super structures of these three dams were removed. The remaining dam sills retain sediments and continue to impound water at this time. The sediments and new riverbanks that were exposed due to the drawdown of the impoundments are known to contain PCB. The exposed sediment banks and sediments have been experiencing slumping and erosion, presenting a significant continuing source of PCB contamination to the Kalamazoo River. A more detailed assessment of the current bank conditions within the former impoundments can be found in Appendix A.

Alternative 3 addresses unstable bank slopes within the MDNR-owned former impoundments using several in-situ technologies. The technologies would be selected considering factors such as bank slope, current vegetative cover, desired habitat features, river velocity, thickness of PCB-containing sediments, and thickness of exposed underlying soils. Based on these factors, several bank types were identified within the former impoundments that are discussed in Appendix A. Photographs of typical bank types are also shown in Appendix A (Figures 9 through 13). Specific erosion control/bank stabilization measures were then developed for each bank type, and are shown on Figures 4 through 11 in Appendix B. Overall, approximately 103,000 linear feet of riverbanks would be stabilized within the MDNR-owned former impoundments. The extent of banks within the former impoundments needing these stabilization measures is shown in plan on Figures 1 through 3 in Appendix B. The extent of the former impoundments was first determined by visual observations, including whether sediment deposits (which have the appearance of gray clay) were present over native soil, and whether a physical feature (e.g., steep bank) would effectively bound the impoundment and prevent deposition of PCB-containing sediments. The affected bank lengths were then estimated based on bank/sediment PCB concentrations equal to or greater than 1 mg/kg. Those banks that showed PCB concentrations greater than 1 mg/kg and showed ongoing slumping and erosion (Appendix A) represented ongoing sources of PCB to the Kalamazoo River and were included in the bank stabilization program. Banks of native granular materials are not impacted by PCB will not require stabilization.

The bank stabilization program would eliminate bank sediments as a source of PCB to the river. The program is designed to prevent sloughing and erosion of former sediments by managing river meander processes and preventing exposure to aquatic species by placing a barrier between bank sediments and associated submerged sediments at the toe of the banks and the river. To accomplish these goals, the stabilization of the riverbanks within the former impoundments would include the following:

> - Bank stabilization techniques are proven and reliable technologies using straight forward construction methods.
> - See Appendix B for more details on how these bank stabilization methods would work.

- Riverbank stabilization would comprise one or more of the proposed bank stabilization methods illustrated in Figures 4 through 11 in Appendix B. Construction would generally consist of the installation of riprap (locally available cobbles, and sand and gravel) above and below the current water line to provide protection against long-term and episodic erosive forces exerted on the stabilized banks. The design would be carried out following well-established channel design procedures (USACE, 1991; USDA, 1998; USFHA, 1989; USDA-SCS, 1977; Gray and Sotir, 1996) to provide erosion protection against a 100-year flood event. Other armoring techniques that may be used below the water line include Reno mattresses, articulated concrete blocks, or other confinement systems filled with sand and gravel. The use of a geotextile below these systems may be needed to protect against wash out in areas where finer sediments are present below the water surface.

- In reaches of the river where there is significant fine-grained sediment thickness (greater than 2 feet) on the river bottom, it is anticipated that additional material would be required on the river bottom to prevent scour and destabilization of the bank during major flood events. The figures in Appendix B show a "launching apron" of riprap to control scour of the sediments from below the bank armoring system. This apron would also act as a cap, or barrier, to direct exposure of aquatic species to submerged sediments at the toe area of the banks.

- Banks with fine-grained sediments that extend more than 1 foot above the normal water surface and exhibit unstable conditions may need additional stabilization measures, as shown on the figures in Appendix B. These measures may include biotechnical erosion control techniques such as Bio-logs and live willow stakes, soil filled geotextile tubes, gabion baskets, etc. The primary purpose of these measures is to provide adequate structural support for the banks while protecting them from scour during major erosion events.

- In order to place the bank stabilization materials, it would be necessary to construct access roads along the affected areas as indicated in Figures 1 through 3 in Appendix B. The access roads would be constructed over soft ground conditions within the exposed floodplain sediments to provide for construction platforms and allow construction access for materials and equipment. The access roads would be 16 feet wide with additional ingress and egress points, and turning areas, as needed. It is anticipated that the access roads would be constructed of local sands and gravels in 12 to 18-inch thick layers. Geotextile and/or geogrid would be used as needed to reinforce the road over soft soils. The roads would be left in place to provide access for continued maintenance of the stabilization measures after completion of the project. This means of egress to the former impoundment areas would also be available to recreational users of those MDNR-owned areas.

> ➢ The banks will be protected both above and below the water line.

The proposed bank stabilization program is designed to provide protection, especially below the water line, against bank scour, which causes blocks of fine-grained materials to fall into the river. Immediately following the completion of construction activities associated with bank stabilization, stream-bank habitat restoration measures would be implemented. Restoration would be accomplished through the re-vegetation of access roads and stabilized banks, the placement of large woody debris and other valuable habitat substrate in the disturbed areas, and the construction of in-river and bank structures that provide habitat and shelter for fish. The objectives of these measures will be to effectively restore areas that currently contain valuable habitat, and to enhance the ecological value of areas that are still recovering after the lowering of impoundment water levels. Refer to Appendix B for a more detailed discussion of the bank stabilization methods.

Prior to the initiation of bank stabilization work, a detailed survey of the affected riverbanks within the former impoundments would have to be performed to more fully characterize existing bank conditions and to obtain data needed to finalize the bank stabilization designs. Following this, clearing and grubbing activities would be performed and a series of support areas would be developed at appropriate locations along the riverbank where construction materials would be staged. Access roads would be constructed from existing roadways to the riverbanks and along the impacted riverbanks to be stabilized. It is anticipated that access roads would be needed on both sides of the former impoundments to provide a platform for construction equipment and allow construction work. These roads would also improve the bearing capacity in areas where the banks are formed of soft exposed sediments. It is possible that stabilization work in parts of the impacted riverbanks may be performed by means of a barge where access from shore is not suitable and where river depths allow. The need for a barge/work platform can be determined at the time the more detailed survey of existing bank conditions is performed. Typically, a barge/work platform would include an excavator mounted on a stationary barge and a transport barge for ferrying materials and personnel to the stationary barge. If barge operation is needed, temporary docks would be constructed, as appropriate, for mooring and launching barges.

> - Bank stabilization would start in 2003 and be complete by the end of 2006.
> - Work would start in the former Plainwell Impoundment, then move downstream to the former Otsego and Trowbridge impoundments.

It is anticipated that the bank stabilization work would be performed sequentially from upstream to downstream in the following order: former Plainwell Impoundment, followed by the former Otsego Impoundment, and then the former Trowbridge Impoundment. Due to the size of the remedial work, it is anticipated that implementation of the proposed bank stabilization measures at the former impoundments would take on the order of 1 year each for the former Plainwell and Otsego Impoundments, and 2 years for the former Trowbridge Impoundment, for a total of 4 years of construction. It is assumed that the construction would commence in 2003. Therefore, the bank stabilization activities for this alternative would be performed in 2003, 2004, and 2005/2006 for the former Plainwell, Otsego, and Trowbridge impoundments, respectively.

An attempt would be made in the work areas to prevent downstream movement of any resuspended materials by the installation of a silt containment system consisting of floating, marine-type silt curtains. During bank stabilization activities, the water column would be monitored on a daily basis for turbidity to assess the effectiveness of the silt curtain. Periodic post-implementation monitoring would be performed to ensure the bank stabilization measures are functioning as intended.

Empirical data generated during the RI indicates that natural attenuation has already been effective in reducing potential risks associated with PCB transport and biological exposure in the Kalamazoo River. Data also support the conclusion that this natural recovery will continue to be effective in reducing risks in the future and, in combination with the source control measures of Alternative 3, achieve the RROs. To verify this conclusion through time and ensure that risks are reduced to acceptable levels, Alternative 3 includes a comprehensive long-term monitoring program to track the effectiveness of the alternative and confirm that the underlying processes of recovery are working as expected. Certain measurements and estimates resulting from the monitoring and analysis program would be used for comparison to performance standards that would be established for the alternative. The program would coincide with the periodic 5-year reviews of a remedy as required by CERCLA. In this way, the monitored natural recovery component of Alternative 3 becomes much more than a "no action" alternative for the river channel upstream and downstream of where source control measures will be implemented.

> - The monitoring program in Alternative 3 would be scientifically rigorous and comprehensive.
> - Every 3 to 5 years, hundreds of fish, water, and sediment samples would be analyzed to closely track improvements in river quality and to monitor decreases in PCB exposure and transport.

The long-term monitoring program would consist of periodic sampling and analysis of fish, surface water, and surface sediment in several reaches of the Kalamazoo River to track the progress of natural recovery and to permit modification of the MDCH fish consumption advisories over time. For fish, these two objectives require two separate fish sampling approaches, one for adult fish and another for yearling fish. To assess the progress of natural recovery in reducing the availability of PCB to fish, monitoring of yearling fish as composite samples is desirable because measurements would be less variable at a given time than measurements of PCB levels in adult fish. Low variation in these measurements aids in the statistical analysis of changes in bioavailability over relatively short periods. Adult fish samples for assessment of the fish consumption advisories would be processed following standard MDCH protocols to obtain samples representative of a standard edible portion (fillet). All whole-body composite and fillet samples would be analyzed to measure PCB concentration and percent lipid.

Target fish species selected for both sampling approaches (e.g., carp and smallmouth bass) would remain consistent with previous fish sampling efforts completed during the RI (1993 and 1997) and during supplemental sampling in 1999. Consistent with past efforts, carp and bass samples would be collected from six different reaches of the river every 5 years for advisory monitoring purposes (about 200 samples) and every 3 years for natural recovery monitoring (about

60 samples), for a total of 30 years. After each round of sampling, an assessment report would be prepared to document trends, verify remedy effectiveness in risk reduction, and make recommendations regarding how and when consumption advisories should be modified.

Similarly, approximately 180 sediment samples and 190 surface water samples would be collected and analyzed every 5 years for a period of 30 years. Samples of surface sediments from six existing transects (approximately 5 samples each) would be analyzed for PCB (Aroclor basis and some congener-specific), TOC, and grain size. The water column would be sampled in 12 pre-established locations and during typical baseflow and high flow periods. Water samples would be analyzed for general water quality parameters, TSS, TOC, and PCB (Aroclor basis and some congener-specific).

To ensure the comparability of these data, every effort would be made to collect and analyze samples in a manner consistent with methods used during the RI and used by the MDEQ for monitoring purposes. Thus, all monitoring would be conducted in accordance with the existing approved FSP (BBEPC, 1993d), HASP (BBEPC, 1993b), and QAPP (BBEPC, 1993a). A detailed *Long-Term Monitoring Plan* would be developed prior to commencement of the monitoring program, with results presented and discussed in a brief report compiled after each monitoring period. The monitoring program is robust and would cost approximately $13.8 million over the 30-year period, as detailed further in Table 4-3. In addition to the benefits of directly monitoring the effectiveness of natural recovery, the data generated through this program would be ideally suited for periodic updates and future enhancements to mathematical models developed for the Kalamazoo River, as described in the *Supplement to the Kalamazoo River RI/FS*.

As discussed in the RI Report, point and non-point sources upstream of the Site and elsewhere in the watershed may be significant with respect to sustaining levels of PCB in fish over the long term. The monitoring program described here will provide useful information to help establish the significance of these sources. Additional investigations would be undertaken by other parties, including the MDEQ, the USEPA, and the appropriate responsible entities to identify specific sources and recommend response actions to control those sources.

Overall Protection of Human Health and the Environment – Alternative 3

> - Stabilizing the riverbanks in the former impoundments would accelerate natural recovery processes and minimize erosion of PCB-containing materials into the Kalamazoo River.
> - Alternative 3 would reduce fish PCB concentrations, reduce PCB transport, and mitigate uncontrolled sources of PCB, thus achieving all three RROs.

In considering the overall protectiveness of any remedial alternative, the PCB concentrations in fish are the key determinant of an alternative's effectiveness and ability to protect human health and the environment. As discussed in Section 4.5, ongoing natural processes in the Kalamazoo River continue to result in decreasing PCB concentrations in surficial sediment and resident fish species. However, the ability for natural attenuation processes to meet RROs for the Site is presently limited by the continuing PCB loads from the eroding bank sediments in the former impoundments. Stabilizing the riverbanks in the former impoundments would address areas of potential erosion and scour of PCB-containing sediments, thus significantly preventing the major remaining source of PCB to the Kalamazoo River and accelerating the natural recovery processes. Natural recovery will continue to effectively reduce PCB bioavailability in sediments and decrease concentrations in fish and the water column without the high level of uncertainty in the ability to effectively implement a capping or dredging alternative, and without the high costs and short-term risks of those intrusive alternatives.

Following implementation of this alternative, fish concentrations are expected to continue decreasing to levels where the advisories may be lifted.

Compliance with ARARs – Alternative 3

No federal chemical-specific ARARs have been identified for this alternative. State chemical-specific ARARs are PCB concentrations of 0.000026 μg/L and 0.00012 μg/L that were developed to meet the Rule 323.1057 Water Quality Standards for protection of human health and wildlife, respectively. As with Alternatives 1 and 2, Alternative 3 would not be expected to achieve the Michigan Part 31 PCB Water Quality Standard for protection of human health (0.000026 μg/L) or the standard for protection of wildlife (0.00012 μg/L). These ARARs would need to be waived to facilitate implementation of Alternative 3.

Several federal and state action- and location-specific ARARs require that permits be obtained for activities included in this alternative. These ARARs include the federal Clean Water Act, the State Wetland Protection Act, the State Inland Lakes and Streams Act, and the State Soil Erosion and Sedimentation Control Act. However, Section 121 (e) of CERCLA codifies USEPA policy that on-site response actions may proceed without obtaining permits. In lieu of actual permits, the USEPA or the MDNR may specify requirements and procedures that should be followed to protect the environment. The substantive requirements and procedures would be followed to the extent practicable. Additional ARARs include the federal Occupational Safety and Health Act (OSHA), and the state equivalent of OSHA (MIOSHA-Act 154), both of which would be complied with as action-specific ARARs during implementation of this alternative.

Long-Term Effectiveness and Permanence – Alternative 3

> - The comprehensive monitoring program will document long-term risk reduction and:
>   - Track the progress of natural attenuation,
>   - Ensure the restored banks are maintained,
>   - Qualitatively assess the impact of PCB transported from upstream of the Site.

As noted previously, long-term reduction in constituent concentrations in sediments would occur as a result of natural attenuation and sedimentation processes, thereby diminishing Site risks over time. Erosion control/bank stabilization measures within the former impoundments would mitigate the ongoing migration of PCB-containing exposed sediments into the water column, thereby accelerating the rate of Site recovery by isolating the most significant identified remaining source of PCB to the system. The stabilized banks would be designed and maintained to be physically stable and effective in terms of isolating the PCB-containing bank sediments over the long-term.

Bank stabilization activities in the former impoundments would result in accelerated reductions in surface sediment PCB and hence fish tissue PCB concentrations over the long term, relative to natural attenuation alone. The permanence of this alternative would be strongly influenced by natural processes (expected to continue over the long term), including transport of PCB-containing sediments from areas upstream of the Site, such as Morrow Lake. These sediments are expected to be transported downstream and deposited in the river, delaying the natural recovery processes in some reaches. Long-term reduction in PCB biota levels would occur to the extent that other PCB sources to the river are reduced or eliminated, that impoundment pool elevations remain at their current levels, that natural processes (e.g., sedimentation and biodegradation) continue to occur in the river, and provided that the restored banks are effectively maintained. Monitoring during and following bank stabilization activities would track the effectiveness and permanence of this alternative.

As indicated in Section 2.5, the bank PCB loads appear capable of sustaining steady-state PCB concentrations in surface sediments of Lake Allegan at a level of 0.4 to 0.8 mg/kg. These levels are 12 to 25 percent of the average observed in 1993/1994 sediment cores. Stabilization of the banks would allow natural attenuation to progress below those levels. The diminishing PCB load forecast presented in Section 2.5 indicated a surface sediment PCB level of roughly 0.25 mg/kg by 2030 or a 92% reduction relative to 1993/1994 levels.

Reduction of Toxicity, Mobility, or Volume through Treatment – Alternative 3

Treatment is not a component of Alternative 3, therefore, reduction of toxicity, mobility, or volume through treatment is not expected. However, stabilizing the banks within the former impoundments would reduce the mobility of PCB under the stabilized areas. The volume and toxicity of PCB would not be reduced through placement of bank stabilization measures; however, exposure to PCB would be greatly limited in those areas. Reduction of PCB exposure and further reduction of PCB mobility in the river is expected to continue through natural processes. The reduction of toxicity, mobility, or volume of in-river sediment would be tracked through implementation of the monitoring program described in Alternative 2.

Short-Term Effectiveness – Alternative 3

> - Every effort would be made to minimize the short-term impacts of Alternative 3, which would likely include:
>   - Increased truck traffic;
>   - Localized disruption of habitat;
>   - Possible PCB releases to surface water; and
>   - Worker safety issues.
> - Because construction would only take about 4 years, these impacts are expected to be minor relative to more complex and intrusive alternatives.

Potential short-term increases in risk to human health and the environment are possible during construction activities. The short-term effects of bank stabilization activities within the former impoundments would include significant but localized disruption/alteration of habitat in certain areas along the riverbanks through the construction of access roads and the stabilization of the riverbanks. Immediately following the completion of construction activities associated with bank stabilization, stream bank habitat restoration measures would be implemented. Restoration would be accomplished through the re-vegetation of access roads and stabilized banks, the placement of large woody debris and other valuable habitat substrate in the disturbed areas, and the construction of in-river and bank structures that provide habitat and shelter for fish. The objectives of these measures will be to effectively restore areas that currently contain valuable habitat, and to enhance the ecological value of areas that are still recovering after the lowering of impoundment water levels.

The short-term impacts of bank stabilization activities within the former impoundments also would include significant localized disruption of the benthic community near the bank toes, potential releases of sediments and PCB to the water column during construction activities, and possible disruption of recreational and other traffic in those areas of the river. The *Supplement to the Kalamazoo River RI/FS* contains a detailed evaluation of the short-term ecological impacts from the implementation of this alternative.

Reasonable and appropriate controls (e.g., silt curtains) would be undertaken/implemented to mitigate PCB releases to the water column during bank stabilization activities, but these controls may not be entirely effective. Equipment required for movement/set-up of various silt curtains may disturb PCB-containing sediment and subsequent releases of PCB could result in increased human health and ecological exposure. Monitoring of turbidity and PCB during construction activities would allow for documenting releases and identifying a need for preventive/mitigative measures, as needed.

Truck traffic (including through residential areas) to deliver materials and equipment would increase for the duration of the project. The truck traffic to implement the bank stabilization activities would involve approximately 70,000 truck trips over a 4-year period to haul riprap and fill materials to the Site. Additional traffic is anticipated to bring other construction materials to the Site, and to haul away trees and debris generated from clearing and grubbing prior to construction activities. This would increase levels of exhaust fumes in the air, noise levels near the work area, and the rate of vehicular accidents. During construction operations, appropriate health and safety practices (OSHA 29 CFR 1910.129) will be followed at the Site through implementing a Site-specific HASP. As a result, it is expected that remediation workers and the community would not be exposed to PCB levels that present unacceptable health risks during construction operations.

As presented in Appendix G, a total of over 170,000 worker-hours is estimated to be required to complete the bank stabilization at the former impoundments. Based on the estimated worker-hours and general accident statistics for labor categories relevant to those expected to be involved with the implementation of this remedial alternative, the estimated risk of at least one worker fatality associated with this remedy is approximately 1 in 51 (2×10^{-2}).

There would also be off-site transportation risks associated with the trucking of clean fill materials to the Site. As presented in Appendix H, this alternative will require the transportation of approximately 441,000 cy of material, representing approximately 70,000 truck trips. Based on an evaluation of national traffic accident data, approximately 3 accidents are predicted for off-site transportation of material necessary for this remedy. This corresponds to a risk of approximately 1 in 170 (6×10^{-3}) that there would be a transportation related fatality during implementation of the bank stabilization remedy, and a risk of about 1 in 4 (3×10^{-1}) that there would be a transportation-related injury.

Implementability – Alternative 3

> ➢ Bank stabilization would employ conventional construction methods, but the volume and type of materials necessary to complete the project will need to be carefully considered during the detailed design phase.

As described in Appendix B, the proposed bank stabilization measures would utilize conventional construction techniques and materials, and most of the necessary equipment and services are readily available. However, due to the size of this project, substantial volumes of construction materials would be required. The availability of certain types of the required materials (e.g., specific sizes of gravel) appears to be limited in the vicinity of the Site. The use of alternate materials or sources of materials would need to be evaluated further during detailed design. The construction is expected to continue over a period of four years assuming that the construction operations at the three former impoundments would be conducted sequentially, upstream to downstream.

As stated previously, access roads would be needed along the entire length of the impacted banks on both sides of the river to provide for a construction platform in soft sediments in the exposed floodplains, and to haul construction materials and equipment to the Site. Construction of access roads would require clearing of trees and debris along the riverbanks. Access roads can be constructed utilizing conventional clearing, hauling, and excavation techniques. It is possible that certain areas along the banks may not be accessible from land, thus requiring water-based construction methods such as having an excavator mounted on a stationary barge and a supply barge where water depths allow.

Since the Site is designated as a CERCLA site, permits are not required for on-site activities; however, the substantive applicable requirements of federal and state regulations would need to be met. With respect to administrative feasibility, negotiations with affected landowners to use and develop access areas would be required.

No specialized labor or equipment is anticipated to maintain the existing dam structures or dam sill elevations, or to address any external PCB sources, should they be identified. However, to properly implement these activities, cooperation and approval by the MDNR, the MDEQ, and the pertinent property owners/responsible parties will be necessary.

Cost – Alternative 3

The estimated capital and O&M costs to implement Alternative 3 are $43,340,000 and $29,846,000, respectively, for a total cost of $73,186,000 (+50%/-30%). This results in an estimated present worth cost to implement bank stabilization within the MDNR-owned former impoundments of approximately $40,679,000. A breakdown of the estimated costs for implementing Alternative 3 is presented in Table 4-3.

4.7 Alternative 4 – River-Wide Capping of Submerged Sediments, Bank Stabilization at the Former Impoundments, Institutional Controls, and Monitoring

> - Alternative 4 builds on Alternative 3's source control efforts by adding a river-wide sediment capping component to contain and isolate PCB in place.
> - Capping all 2,895 acres of submerged sediment is estimated to take approximately 40 years.
> - In deeper reaches, the cap would be about 2 feet thick, placed on top of a geotextile layer.
> - Extensive temporary access roads and docks would be built after clearing and grubbing of vegetation.

Alternative 4 involves the containment, through capping, of PCB-containing submerged sediment at the Site, together with the components of bank stabilization and monitoring as discussed under Alternative 3. A total of approximately 2,895 acres would be capped from Morrow Dam to the Lake Allegan Dam. Overall, approximately 545 acres of free-flowing reaches, 250 acres of former impoundments and 2,100 acres of current impoundments would be capped. The free flowing reaches include the stretches from Morrow Dam to Main Street, Plainwell and from Trowbridge Dam to the Allegan City Line. The former impoundment stretches include from Main Street, Plainwell to Plainwell Dam, from Otsego City Dam to Otsego Dam, and from Otsego Dam to Trowbridge Dam. The current impoundment stretches include from Plainwell Dam to Otsego City Dam, from the Allegan City Line to Allegan City Dam, and from Allegan City Dam to Lake Allegan Dam.

Construction would begin with development of a series of support areas at appropriate locations (examples of potential locations are provided in Figures 2 through 9 in Appendix E) along the river, where capping materials would be staged and river access obtained to allow placement of cap materials through the use of water-based equipment (e.g., barges and work boats). Access roads would be constructed from existing roadways to the deeper impoundments, where temporary docks would be constructed. In narrower, nonimpounded stretches, access roads would be constructed on one side of the river to allow placement of cap materials with land-based equipment (e.g., excavators, backhoes, and front end loaders). Access roads would be constructed on both sides of the river in the former impoundment areas that do not have sufficient draft and are too wide to completely reach with land-based construction equipment from only one side. The riverbanks for the majority of areas are tree lined with shrub growth down to the water line (see Appendix B). Fallen trees, snags, and overhanging branches are present in most areas. Therefore, access areas and roads would require extensive grubbing and clearing prior to construction and possible relocation of utilities. Before placing cap materials, a comprehensive bottom survey of the Site would be performed, and identified obstacles would be removed, or additional cap materials would be provided to cover them in place. Results of a diver-based investigation of Lake Allegan conducted in September 2000 are described in the *Supplement to the Kalamazoo River RI/FS*. The diver investigation and a bathymetric survey were done to more fully characterize conditions (including debris and obstructions) at the bottom of impounded portions of the Kalamazoo River.

Capping materials likely would include geotextile in shallower areas, and available sands and armoring materials such as gravels/cobbles. It is currently assumed that up to 2 feet (nominally) of sand would be placed in the current and former impoundments and in deeper portions of the free-flowing reaches. Approximately 6 inches of the two feet of sand would likely be replaced with gravel/cobbles in the cap for the free-flowing reaches to withstand forces due to higher flow velocities. A geotextile would be placed as a base layer before the sand and gravel is placed in all areas of the Site except for the deeper portions of Lake Allegan. The geotextile would serve as both a separation layer and to provide stability. During detailed design of this alternative, design requirements would be balanced against site constraints. For example, specification of the required cap thickness for chemical and biological isolation of PCB may be constrained by available water depth and the expected decrease in flood storage in the area. Cap thickness would need to be restricted to prevent significantly narrowing the width of the river by completely filling the shallow near bank areas. Additionally, cap materials would need to be sized and the required gradation determined to protect against high flows/velocities. Constricting river flow in one area could result in erosion of other areas by the river to maintain required natural flow capacity.

Capping would be performed in one stream segment at a time, starting from upstream and moving downstream. This sequence would address concerns regarding construction-related recontamination of downstream areas. Segments would be determined based on production rate and the presence of logical break points in the river (based on morphology). Efforts would be made to minimize disruption of river-related activities.

Capping areas would be isolated by the installation of a multiple-layered silt containment system consisting of floating, marine-type curtains. Temporary docks would be constructed, as appropriate, and would be used for mooring and launching work boats, scows, and barges. For capping being performed from the water, cap materials would be loaded into scows and transported to the work areas. A loader mounted on a second barge would be used to off-load and place the materials. For capping being implemented from the banks, cap materials would be transferred by crane either from loaded trunks or stockpiles and either placed directly into the river or with the use of conveyors. It would also be possible for sand to be transferred and placed in slurry form using a diffuser or other discharging system. Due to the size of the project, it is anticipated that implementation of this alternative (including bank stabilization) would take approximately 40 years. This would include dual capping operations being performed simultaneously in Lake Allegan which is the widest portion of the Site, and therefore could accommodate the two separate work crews at the same time. During capping activities from within the river, water levels would be monitored on a daily basis to determine whether required drafts are available for the barges. The water column also would be monitored on a daily basis for turbidity to gage the effectiveness of the silt curtain. Post-implementation monitoring would be performed to gage whether the cap is performing as intended. Monitoring and O&M are assumed over a 30-year period following completion of construction for costing purposes. The monitoring programs outlined for Alternative 3 also would be implemented to evaluate natural attenuation and determine when fish consumption advisories may first be relaxed and then eventually lifted for the various species. Additional institutional controls to be implemented include designations of "no wake" zones in near shore areas of the current impoundments and placing restrictions on marine construction and dredging throughout the Site. These efforts would be undertaken to maintain cap integrity so that the cap is functioning as intended.

Overall Protection of Human Health and the Environment – Alternative 4

> ➢ **Capping of the river sediments would eventually isolate PCB and enhance natural attenuation; however, human use and quality of the river would be disrupted for the entire 40 years of construction.**

Ongoing natural processes in the Kalamazoo River continue to result in decreasing PCB concentrations in surficial sediment and resident fish species. Bank stabilization would be protective to human health and the environment as discussed in Section 4.6. Capping of the current river sediment surface would further isolate PCB-containing sediments. Previous studies by the United States Army Corps of Engineers (USACE), as well as experience at other capping sites, have shown that capping is effective in reducing PCB bioavailability to aquatic and terrestrial organisms by isolating PCB and mitigating PCB migration from sediments to the water column (as discussed in Appendix C). This reduction in PCB bioavailability results in associated decreases in fish PCB concentrations. Surficial PCB concentrations in river sediment would decrease substantially following cap installation.

Additionally, natural processes are expected to continue in the river, although they will likely be disrupted during implementation of this alternative. During implementation of Alternative 4, appropriate controls, such as the use of a silt containment system and daily monitoring would be utilized to mitigate/contain the effects of disruptive capping operations to human health and the environment. However, these controls may not be completely effective at preventing releases.

Maintenance of the fish consumption advisories would continue to be protective of human health at the Site. Following implementation of this alternative, fish concentrations are expected to continue decreasing to levels where the advisories may be lifted.

Compliance with ARARs – Alternative 4

No federal chemical-specific ARARs have been identified for this alternative. State chemical-specific ARARs are PCB concentrations of 0.000026 µg/L and 0.00012 µg/L that were developed to meet the Rule 323.1057 Water Quality Standards for protection of human health and wildlife, respectively. As with Alternatives 1, 2, and 3, Alternative 4 would not be expected to achieve the Michigan Part 31 PCB Water Quality Standard for protection of human health (0.000026 µg/L) nor the standard for protection of wildlife (0.00012 µg/L). These ARARs would need to be waived to facilitate implementation of Alternative 4.

Several federal and state action- and location-specific ARARs require that permits be obtained for activities included in this alternative. These ARARs include the federal Clean Water Act, State Wetland Protection Act, State Inland Lakes and Streams Act, and State Soil Erosion and Sedimentation Control Act. However, Section 121 (e) of CERCLA codifies USEPA policy that on-site response actions may proceed without obtaining permits. In lieu of actual permits, the USEPA or the MDNR may specify requirements and procedures that should be followed to protect the environment. The substantive requirements and procedures would be followed to the extent practicable. Additional ARARs include the federal OSHA, and the state equivalent of OSHA (MIOSHA-Act 154), which would both be complied with as action-specific ARARs during implementation of this alternative.

Long-term Effectiveness and Permanence – Alternative 4

> - The primary benefits of Alternative 4 come from bank stabilization; despite its very large scale, capping does not add significant effectiveness.
> - Capping would destroy or significantly alter the benthic community along the entire river.
> - Maintenance of the cap would be critical to its long-term effectiveness.

Implementation of Alternative 4 could be both effective and reliable over the long term as a means of accelerating reductions in potential human health and ecological risks at the Site, but these reductions in exposure would be primarily attributable to the bank stabilization efforts. Implementation of this alternative is expected to substantially isolate PCB-containing materials in the current and former impoundments and other portions of the

Site. While implementation of this alternative would serve to significantly reduce the long-term bioavailability and scour/transport of PCB in the submerged sediments throughout the Site, it is estimated to take 40 years to complete, with little benefits beyond those achieved through bank stabilization in a 4-year timeframe.

Once in place, the effectiveness and protectiveness of the cap is dependent upon implementation of a long-term maintenance and monitoring program. In the short-term, the benthic community would be significantly altered or destroyed as a result of cap placement. The exact period of time that would be required for the benthic community to recover from such an event is unknown. Due to the homogenization of stream bottom substrate and morphology, benthic organism and fish abundance and diversity are unlikely to fully recover. It should also be noted that adding sufficient cap/armor material to meet all relevant design criteria could alter flood flows and reduce flood storage capacity within the Kalamazoo River system. This could have the effect of increasing bank erosion in bank areas that are currently not a significant source of PCB to the river, which in turn require modifications to the cap design that limit its effectiveness or may require stabilization of bank areas outside the former impoundments.

The permanence of this alternative would be strongly influenced by natural processes (expected to continue over the long term), including transport of sediments from areas upstream of the Site. These sediments are expected to be transported downstream and deposited in the river. This process would be ongoing (even during cap placement), and could increase surficial sediment PCB concentrations in the river after cap placement. Long-term reduction in PCB biota levels would occur to the extent that: 1) PCB sources to the river are reduced or eliminated, 2) natural processes (e.g., sedimentation and biodegradation) continue to occur in the river, and 3) the cap is functioning as intended.

Reduction of Toxicity, Mobility, or Volume through Treatment – Alternative 4

Active treatment is not a component of Alternative 4, although naturally occurring PCB biodegradation processes may be ongoing and would continue even if the submerged sediments are capped. Therefore, significant reduction of toxicity, mobility, or volume through treatment is not expected.

Short-term Effectiveness – Alternative 4

> ➤ The 40-year time frame, the substantial increase in truck traffic, possible PCB releases to the river during construction, and widespread destruction of the benthic community combine to limit the short-term effectiveness of Alternative 4.

The short-term effects of capping in the river would include significant destruction of the benthic community, potential releases of resuspended PCB to the water column during implementation of capping activities, and possible disruption of recreational activities and boat traffic in the river. The short-term effectiveness of the bank stabilization portion of this alternative was described previously in Section 4.6. Truck traffic to deliver capping materials and equipment would increase substantially, and persist for the duration of the project. Approximately 2.5 million one-way truck trips to and from the Site would likely be required over a 40-year period. This additional traffic increases the likelihood of accidents, noise levels, potential for exhaust fumes in the air, and effects of other related activities.

Reasonable and appropriate controls (e.g., silt curtains) would be implemented to mitigate PCB releases to the water column during capping activities, but these controls may not be entirely effective. For example, while silt curtains aid in containment of suspended solids during capping activities, it is not expected that the curtains will prevent all such releases in the vicinity of capping operations. Increased water depths and wave-induced turbulence could reduce the effectiveness of silt curtains (USEPA, 1994b). The use of silt curtains in currents greater than 1.6 feet per second (fps) is discouraged due to reductions in effectiveness (St. Lawrence Centre, 1993). In addition, equipment required for movement/set-up of various silt curtains may disturb and suspended PCB-containing sediment. Daily monitoring of turbidity and PCB during capping activities would document releases and identify the need for any preventive/mitigative measures.

In general, remediation workers and the community would not be exposed to PCB levels that present unacceptable health risks during capping operations if appropriate health and safety practices (OSHA 29 CFR 1910.129) are followed through implementation of a Site-specific HASP. Appropriate controls, such as the use of a silt containment system and daily monitoring, would be utilized to mitigate/contain the effects of disruptive capping operations to the environment. Implementation of this alternative could increase potential risk levels associated with the Site on a short-term basis as a result of sediment resuspension and other related activities during capping operations.

As presented in Appendix G, a total of over 2.6 million worker-hours is estimated to be required to complete the river-wide containment of submerged sediments and bank stabilization. Based on the estimated worker-hours and general accident statistics for labor categories relevant to those expected to be involved with the implementation of this remedial alternative, there is a 40 percent chance of at least one worker fatality during this remedy.

There would also be off-site transportation risks associated with the trucking of clean fill materials to the Site. As presented in Appendix H, this alternative will require the transportation of approximately 14,530,000 cy of material, representing approximately 2.5 million truck trips. Based on an evaluation of national traffic accident data, approximately 176 accidents are predicted for off-site transportation of material necessary for this remedy. This corresponds to a risk of approximately 1 in 3 (3×10^{-1}) that there would be a transportation related fatality during implementation of the subaqueous capping remedy, and an estimated 15 collision-related injuries.

> ➢ **Changing the nature of in-stream habitats, removal of large numbers of mature trees and vegetation for access road construction, and the associated impacts on wetland and upland habitats also limit the short-term effectiveness of the capping alternative.**

Capping of approximately 50 miles of river would be expected to significantly alter or destroy the benthic community in this area, which in turn could significantly alter the overall ecosystem (e.g., in-stream habitats) for an extended period of time in this portion of the Site. The potential ecological impacts of Alternative 4 are discussed in detail in the *Supplement to the Kalamazoo River RI/FS*. Capping would cause short-term water column impacts, changes to in-stream morphology (i.e., creation of shallow areas changing the nature of in-stream habitats), in-stream benthic habitat destruction, and substrate alteration. The latter could include destruction of submerged wetlands and homogenization of ecologically valuable heterogeneous sections of the river.

The most significant impacts to wetland and terrestrial resources for the capping portion of this alternative would be associated with the removal of mature trees and construction of access roads along the banks of the entire 50-mile Site. These impacts include large amounts of wetland and upland habitat destruction, habitat fragmentation, species isolation, and production of additional "edge" habitat. These effects would be especially pronounced in areas where the riparian corridor is narrow and may serve as an important wildlife corridor between areas of more dense vegetation. Impacts would be less significant in areas containing extensive and high quality riparian corridor habitat. Birds, mammals, reptiles, and amphibians are all likely to be impacted from the habitat destruction from this alternative. These biota include several species that are on the state and/or federal threatened and endangered lists. Benthic feeding and piscivorous species would be further impacted by the degradation to the aquatic habitat and communities that comprise their prey base.

The length of time it would take for the benthic community to recover from the effects of capping is unknown. The recovery time for in-stream areas where cap material is applied would depend on the resulting substrate and stream morphology. Homogenization of the stream bottom and stream morphology makes recovery of benthic organism and fish abundance and diversity unlikely. Likewise, recovery of forested areas after road construction is likely to take decades. For all the above reasons, the implementation of this alternative is likely to cause significant long-term impacts to the habitat and biota within the Site over the 40-year project duration.

Implementability – Alternative 4

> ➢ Despite the use of conventional construction techniques and readily available equipment and services, the massive volume of capping materials necessary to cover 2,895 acres may pose implementation problems.

The proposed bank stabilization and sediment capping measures utilize conventional construction techniques and materials, and the necessary equipment and services are readily available. Although the technologies to be used in this alternative are proven, and most of the necessary materials and services are available, no known river capping project has approached the scale of the combined sediment areas of the current and former impoundments and free-flowing reaches at the Site (see Appendix C for additional details and experience from other sites). Placement of geotextile through the water column may pose challenges during construction. Limited access, the presence of debris, variable flows, and insufficient water depths will make it difficult to place a uniform layer of cap material on the river bottom.

Substantial volumes of cover materials (up to 10 million cy) and associated construction equipment would be required over a prolonged period of time (several decades). This would burden the current road system and may eventually require road maintenance and possibly bridge reconstruction. The availability of certain types of the required materials (e.g., specific sizes of gravel) appears to be limited in the vicinity of the Site. The use of alternate materials or sources of materials would need to be evaluated further during detailed design.

Average water depths in the various segments of the Kalamazoo River vary between two and seven feet (Table 2, Appendix E). In the shallower areas, placement of capping materials would significantly alter the natural hydraulics of the river, including a substantial decrease in flood storage capacity. These lower average water depths limit the thickness of the cap that can be placed and may, therefore, result in a less effective cap. Placement of two feet of material in shallow nearshore areas could extend the riverbank thereby reducing river width.

Since the Site is designated as a CERCLA site, permits are not required for on-site activities; however, the substantive, applicable requirements of Federal and State regulations would need to be met. With respect to administrative feasibility, negotiations with affected landowners to use and develop access areas would be required. No specialized labor or equipment is anticipated to maintain the existing dam structures or dam sill elevations, or to address any external PCB sources, should they be identified. However, to properly implement these activities, cooperation and approval by the MDNR, the MDEQ, and pertinent property owners/responsible parties will be necessary.

Cost – Alternative 4

The estimated capital and O&M costs to implement Alternative 4 are approximately $961,980,000 and $772,402,000, respectively, for a total cost of $1,734,382,000 (+50%/-30%). This results in a total estimated present worth cost to implement Alternative 4 of approximately $300,494,000. A breakdown of the estimated costs for implementing Alternative 4 are presented in Table 4-4.

4.8 Alternative 5 - River-Wide Dredging of Submerged Sediments with Upland Confined Disposal, Bank Stabilization at the Former Impoundments, Institutional Controls, and Monitoring

> - The river-wide dredging project in Alternative 5 calls for a total of 16,000,000 cy of sediment to be removed from the river.
> - The dredged sediments would be transferred to three upland CDFs for long-term storage.
> - Sediments in the CDFs would consolidate over 3 to 5 years and then be capped or covered to permanently isolate them from the environment.
> - The dredging project would take about 25 years and would completely disrupt the existing ecosystem.

Alternative 5 includes removal of PCB-containing submerged sediment at the Site with a series of hydraulic dredges and pumping the dredged material slurry to one of three Confined Disposal Facilities (CDFs) constructed on upland areas adjacent to the river. The sizes of the three CDFs necessary to contain the dredged material generated during dredging range from 135 to over 770 acres. These CDFs would serve two purposes: 1) acting as a sedimentation basin to separate sediment solids from carriage water; and 2) to permanently isolate the PCB-containing dredged material from the environment.

Following the completion of dredging, the dredged material within the CDFs would be allowed to consolidate for a period of three to five years to facilitate placement of a long-term cap or cover. The large quantity of decanted carriage water generated during the dredging process would be collected from the CDFs and treated prior to discharge back to the Kalamazoo River and Lake Allegan. The unit process operations used for treatment of the water include flocculation, sedimentation, dual-media filtration, and two-stage activated carbon adsorption. Water treatment facilities would be constructed adjacent to each of the three CDFs to minimize the number of the water treatment facilities and per gallon treatment costs. This approach also minimizes the overall distance that overflow water from the CDF would need to be pumped prior to treatment and the number and lengths of pipe required to support dredging and water treatment operations. Despite the efforts to minimize the capacity of the water treatment facilities, the three facilities would range in size from 3 million gallons per day (MGD) in the upper reaches of the river to 20 MGD serving a CDF adjacent to Lake Allegan. Treatment plant operations would also include monitoring the discharge effluent to ensure compliance with applicable standards. Stabilization of the former impoundment banks, as described in Alternative 3, would be implemented after dredging is completed in the former impoundment reaches (the first such area being addressed approximately 12 years after the start of construction) to ensure that PCB-containing sediments from the bank areas would not erode into the river. The institutional controls and monitoring as discussed in Alternative 3 also would be performed as part of this alternative.

Dredging would be performed using a shallow-draft hydraulic cutterhead dredge. This type of equipment has been used at several sediment removal projects in the United States, as discussed in Appendices D and E. Given the water depth and debris-related issues for much of the river (see Table 2 in Appendix E), a 12-inch hydraulic cutterhead dredge would be used in all areas with the exception of Lake Allegan. The deeper water depths within the lake would facilitate use of a larger 18-inch hydraulic cutterhead dredge. Hydraulic dredges are best-suited for working in the shallow depths of a river system like the Kalamazoo since they typically have less draft (< 2 feet) and can work their way into even shallower near-shore areas by excavating a channel. Mechanical dredges are not as capable of working in these conditions since they have larger draft requirements and also must be supported by additional scows or barges used to transport dredged material to shore-based rehanding facilities.

The anticipated sediment removal rate for the Site with the exception of Lake Allegan is 600 cy/day. This removal rate is an upper-end maximum value based on 24 hours per day operation, 6 days per week, over a 10-month construction season. The 600 cy/day removal rate is based on experience at other sites where similar hydraulic dredging equipment has been used under operating conditions similar to those expected in the Kalamazoo River. While some of these recent experiences have only been able to attain production rates of approximately 300 cy/day (e.g., Manistique Harbor), the 600 cy/day rate used in this alternative is an upper-bound production rate using 24-hours per day as an overall operating period. For dredging within Lake Allegan, it is assumed that dredging rates of 2,000 cy/day could be achieved because access and river bottom constraints would be less problematic and, therefore, allow for the simultaneous operation of two larger-sized dredges. These dredging rates assume the availability of sufficient land within the immediate vicinity of the Site to allow for the construction of the three large CDFs that can be built to contain the maximum production from the dredging equipment. Additional discussion of dredge production rates at environmental dredging projects is provided in Appendix E.

The amount of sediment that would be dredged from the Kalamazoo River under this alternative is a function of the target dredging depth identified for each reach. The initial target dredging depths were estimated using the maximum depth at which PCB has been detected in sediment within each reach plus an additional 6-inch overdepth layer (Figure 1 in Appendix E). Using this approach the initial volume or quantity of sediment that would be removed during "first-pass" dredging is approximately 13,870,000 cy. In addition, the gross inefficiencies associated with dredging equipment would require the removal of additional sediment below the initial target depths. The final dredging depth is thus based on the initial target depth, plus the removal of a second 6-inch overdepth layer during a final "clean up" dredging pass. The thickness of the overdepth layer (6 inches) was determined based on the smallest layer of sediment that can reasonably be removed using a small hydraulic dredge operating at close to peak efficiencies. Allowing for this overdepth dredging, which is necessary to even attempt to achieve acceptable (low) PCB residual concentrations, the total estimated volume of sediment to be dredged from the Site is 16,242,000 cy. Approximately one third of this sediment volume (5,593,000 cy) is from the Kalamazoo River between Morrow Dam and the Allegan City Dam with the remaining two thirds (10,649,000 cy) located in Lake Allegan. The dredging depth information is summarized below on a reach-specific basis, including the anticipated depth of dredging and the resulting sediment volumes for both the first- and second-pass dredging cuts. The dredged volumes also include approximately 262,000 cy of bank materials that may slough into the channel during dredging in the former impoundment reaches.

River Reach	Dredged Depth (in)	First-Pass Dredged Volume (cy)	Second-Pass 6-in Overdepth Volume (cy)	Total Dredged Volume (cy)
Morrow Dam to Portage Creek	42	476,000	68,000	544,000
Portage Creek to Main Street, Plainwell	18-30	1,000,000	267,000	1,270,000
Main Street, Plainwell to Plainwell Dam	30	232,000	39,000	271,000
Plainwell Dam to Otsego City Dam	42	531,000	74,000	605,000
Otsego City Dam to Otsego Dam	18-60	481,000	64,000	545,000
Otsego Dam to Trowbridge Dam	18-42	705,000	97,000	802,000
Trowbridge Dam to Allegan City Line	30	694,000	139,000	833,000
Allegan City Line to Allegan City Dam	42	633,000	90,000	723,000
Allegan City Dam to Lake Allegan Dam	24-36	9,115,000	1,534,000	10,649,000
Total (rounded)		13,870,000	2,372,000	16,242,000

At a production rate of 600 cy/day, and a conservatively robust assumption of 240 working days per calendar year, the maximum annual removal rate is 144,000 cy per year. Within Lake Allegan, where larger dredging equipment could be operated at higher production rates, and the potential for two dredges operating simultaneously could be considered, production rates of 2,000 cy/day might be achieved. With a total removal volume of over 10.6 million cy, applying this production rate results in a total dredging time of 23 years to complete the Lake Allegan portion of the Site alone.

> ➢ Silt curtains, water quality monitoring, and measurements of PCB in caged fish would all be implemented to mitigate and gauge the impact of dredging on water quality.

In an attempt to minimize the water quality impacts, Alternative 5 includes both hydraulic controls and water quality monitoring. The hydraulic controls include a double ring of silt curtains surrounding the dredge. The water quality monitoring would include an assessment of PCB in the sediment migrating away from the dredge by measuring

TSS, particulate PCB concentrations associated with solids in the water column, and PCB concentrations in caged fish. The use of caged fish will provide a reliable indicator of water column impacts by integrating exposure conditions over a longer time period, as well as assessing the overall bioavailability of PCB within the water column during dredging.

> ➢ Difficulties anticipated during dredging include the need to remove or address debris (junk, rocks, trees) that would interfere with the dredge, and the need to construct extensive access roads, on-shore processing facilities, and three new landfills (CDFs) to contain PCB-contaminated sediments in local communities.

Prior to dredging, the results of the August 2000 bathymetric survey using side-scan sonar and the September 2000 diver-based investigation of the bottom of Lake Allegan (provided in the *Supplement to the Kalamazoo River RI/FS*) would be reviewed to more fully characterize conditions (including debris and obstructions) at the bottom of the Kalamazoo River. Since debris and obstructions can severely hamper the effectiveness and production rates of all types of dredging equipment, a comprehensive debris survey for all areas of the Site must be performed prior to detailed design work, and appropriate grubbing and clearing performed prior to initiating dredging operations. In addition, bank areas that may become unstable following dredging would be identified, and appropriate measures taken to clear those slopes or stabilize them in order to minimize impacts to the dredging operation or nearshore structures.

Following this activity, a series of support areas would be developed at appropriate locations (currently estimated at 17) along the river, as shown on Figures 2 through 9 in Appendix E. These locations would be used to stage dredging equipment and materials, and provide river access. Access roads would be constructed from existing roadways to the deeper impoundments, where temporary docks would also be constructed. In narrower, non-impounded stretches, access roads would be constructed on one of the banks. To provide access for bank stabilization activities (as described in Section 4.6), access roads would be constructed on both sides of the Kalamazoo River in the former impoundment areas. The riverbanks for the majority of areas have tree and shrub growths down to the water line. Fallen trees, snags, and overhanging branches are present in most areas. Access areas and roads would need to be cleared prior to construction.

As mentioned above, the general approach for dredging consists of two passes, including an initial, or first-pass, attempt to remove the bulk of the PCB-containing sediment and a second-pass to assist in removing the PCB-containing sediments that will remain on the sediment's surface following the first-pass dredging. The general dredging approach also includes dividing the river into three segments:

- Segment A - Morrow Dam to the Plainwell Dam;
- Segment B - Plainwell Dam to the Allegan City Dam; and
- Segment C - Lake Allegan.

> - The river would be divided into three dredging zones, with one CDF and one water treatment facility for each.
> - The zone approach would allow first-pass dredging to take place in parallel (more than one area at a time) to shorten the project time period to the extent possible.

The three segments identified above were established using logical breakpoints in the river and the logistical constraints associated with distance limitations for effectively pumping dredged sediment through pipelines using the sizes of dredges and booster pumps that are applicable to the geomorphology of this river. To maximize cost effectiveness, a single CDF and associated water treatment facility (WTF) has been sized to support dredging in each of these three segments of the river. In assembling a dredging alternative, it is important to keep in mind that increasing the number of CDFs will significantly increase the overall cost of the alternative, including both sediment disposal and water treatment costs.

The dredging would begin following a five-year period for design, land acquisition, and permitting, and a year to construct the CDFs and WTFs (due to the large amounts of materials needed to construct the CDFs, it may be necessary during detailed design to consider extending this schedule). The overall dredging schedule is 25 years long and has been optimized to complete as much of the project as possible in parallel including the first-pass dredging within each of the three segments. First-pass dredging would occur over a 21-year period including 12 years in Segment A, 21 years in Segment B, and 19 years in Segment C.

> - If parallel dredging in multiple locations was not incorporated where possible, the dredging project would take approximately 60 years to complete.

Consistent with environmental dredging practice, second-pass dredging would not be conducted in parallel. Rather, the second-pass dredging would be conducted in an upstream to downstream direction to minimize the effects of upstream dredging on downstream reaches. The second-pass dredging would begin in Segment A at the end of year 12 of the dredging schedule and would continue for approximately three years. The second-pass dredging in Segment B would begin at year 19 of the dredging schedule and would proceed in parallel with first-pass dredging within the segment. Both dredging passes can be conducted in parallel within this segment given its length, configuration, and the requirement that all dredging in the immediately upstream segment (Segment A) be completed. Second-pass dredging for Segment C would begin at year 22 of the dredging schedule and continue for a three-year period. In understanding the dredging, it is important to note that if the dredging was completed in an upstream to downstream direction with no parallel scheduling (i.e., no simultaneous operations of multiple dredges), the overall dredging schedule would extend over a 60-year period.

Dredging also requires building a number of construction support zones including docks, moorings, and lay-down areas. These support zones would require the construction of access roads. While efforts would be made to minimize impacts to public use of the river, the presence of dredging equipment including dredges, pipelines, and work boats, operating on a 24 hours per day, 6 days per week basis, will require maintenance of large exclusion zones throughout the river.

Alternative 5 assumes that removed sediments would be hydraulically transferred to upland CDFs, which would serve to initially separate sediments from the carriage water and then allow for consolidation and dewatering of the removed sediments within the cells used for long-term containment. Based on a maximum dredged material slurry pumping distance of 10 miles, three CDFs would be required, one near Plainwell Dam, a center-segment CDF near Trowbridge Dam, and one near Lake Allegan. Using a 20-foot design height and side slopes of 1:3, these CDFs would occupy areas of 135, 282, and 771 acres, respectively, as shown on Figures 5, 8, and 9 in Appendix E.

The conceptual design of the CDFs assumes clearing and grubbing of the selected areas, followed by initial placement of one foot of narrow-grade sand bedding. The 20-foot high berms that form the CDFs would be constructed using native soils. A polyethylene liner would be placed on the floor and side-slopes of the CDFs to prevent leakage of the dredged material slurry out of the walls and floor of the CDFs. All three CDFs would be built during the first construction season.

WTFs would be located adjacent to each of the three CDFs. Treatment operations would consist of flocculation, sedimentation, dual-media filtration, and two-stage activated carbon adsorption with monitoring and discharge of treated water to the Kalamazoo River or Lake Allegan. WTFs sized for 3 MGD and 10 MGD will be required for treatment of first-pass carriage waters from the Kalamazoo River and Lake Allegan, respectively. Second-pass overdepth dredging in the river would begin by year 13 and would continue until year 21, when second-pass dredging would begin in Lake Allegan. WTFs would be sized to accommodate 6 MGD and 21 MGD during second-pass dredging of the Kalamazoo River and Lake Allegan, respectively. Water treatment capacity of 9 MGD would be required for Segment B during years 19 to 21 of the program, when simultaneous dredging occurs in two portions of the segment.

After several years of consolidation, the CDFs would be covered by a 2-foot sand layer, polyethylene liner, and 2 feet of loam and/or topsoil. A total of 54 shallow monitoring wells would be placed at 1,000-ft intervals along the perimeters of the three CDFs. The WTFs would be decommissioned at the completion of the consolidation period.

Overall Protection of Human Health and the Environment – Alternative 5

> - Despite the large scale of sediment removal, dredging does not add significant risk reduction beyond that gained from bank stabilization.
> - River-wide dredging will destroy 50 miles of the Kalamazoo River's benthic community; the length of time necessary for recovery is unknown.

Removal of all PCB-containing river sediment and stabilization of exposed sediment would reduce the bioavailability of PCB to aquatic and terrestrial organisms, resulting in decreases in fish PCB concentrations. Surficial PCB concentrations in river sediment would decrease following dredging and bank stabilization, and would continue to decrease over the long term, but the reductions in risk associated with the declining fish tissue concentrations are primarily attributable to the bank stabilization component of the alternative. Without bank stabilization, the alternative would not achieve nearly the same levels of risk reduction.

While dredging alone may provide for a small amount of risk reduction, this level of effectiveness is predicated on the optimistic assumption that dredging would achieve a low target residual PCB concentration in the sediment. This optimistic assumption does not take into account the redistribution and deposition of PCB-containing sediment that will become the new surficial sediments. The PCB concentration of these new surficial sediments is important as they control post-dredging environmental exposure conditions.

The small environmental benefit that may be associated with dredging comes with a premium as it relates to negative environmental impacts. The level of habitat destruction associated with completely removing the entire benthic community along a 50-mile river system is unprecedented. Not only will the native benthic community be eliminated, but the habitat including sediment substrate and water depth will be permanently altered. The environmental consequence of these actions including impacts to future fish community structure would undoubtedly be significant. The limited benefits associated with wide-scale dredging must also be balanced with the environmental and economic impacts of transforming over 1,200 acres of land into CDFs.

Maintenance of the fish consumption advisories would continue to be protective of human health at the Site. Following implementation of this alternative, fish concentrations are expected to continue decreasing to levels where the advisories may be lifted.

Compliance with ARARs – Alternative 5

> - Some dredged materials may have to be disposed of at a TSCA hazardous waste facility.
> - Portions of the Clean Water Act, Clean Air Act, River and Harbors Act, and the Michigan Inland Lakes and Streams Act and Solid Waste Management Regulations may apply, as well as certain OSHA and USDOT requirements.
> - As with all other alternatives, the Michigan water quality standards would need to be waived.

No federal chemical-specific ARARs are identified for this alternative. State chemical-specific ARARs are PCB concentrations of 0.000026 μg/L and 0.00012 μg/L in surface water that were developed to meet the Rule 323.1057 Water Quality Standards for protection of human health and wildlife, respectively. As with Alternatives 1 through 4, Alternative 5 would not be expected to achieve the Michigan Part 31 PCB Water Quality Standard for protection of human health (0.000026 μg/L) or the standard for protection of wildlife (0.00012 μg/L). These ARARs would need to be waived to facilitate implementation of Alternative 5.

Other applicable chemical-specific ARARs include portions of the Clean Water Act as it applies to discharges from waste water treatment facilities. These facilities would be designed to meet those requirements as specified under the Michigan Water Resources Commission Act. Portions of the TSCA could be considered applicable to disposal of any sediments with PCB exceeding 50 mg/kg of dry solids; however, based on analytical results of in-situ sediments, it is expected that dewatered sediments removed in accordance with Alternative 5 will rarely exceed the criterion of 50 mg/kg.

Several substantive action- and location-specific ARARs must be met because Alternative 5 includes disturbance of materials in the Kalamazoo River and floodplains of the former impoundments. These ARARs include applicable portions of the Clean Water Act, River and Harbors Act, and the Michigan Inland Lakes and Streams Act. USEPA Executive Order 11988, which requires the minimization of adverse impacts to the floodplain, also applies. Construction of the CDFs would likely occur outside of the geographic bound of the Superfund Site and would, therefore, require a number of permits and regulatory approvals (e.g., under the Michigan Solid Waste Management Regulations) prior to their construction. Analyses related to these permits may include further environmental impact and cost-benefit analysis. Unforeseen permitting and siting problems associated with locating CDFs to contain PCB-contaminated sediments in the area communities could result in further delays. Additional ARARs include the federal TSCA, OSHA, United States Department of Transportation (USDOT) transporting and handling requirements, and the state equivalent of OSHA (MIOSHA-Act 154), which would each be complied with during implementation of this alternative.

It is possible that disruption or destruction of identified endangered species and/or their habitats could occur, although precautionary measures would be undertaken that would be directed toward compliance with related ARARs during implementation of this alternative. Section 404 of the Clean Water Act (33 U.S.C. 1344) regulates discharge of dredged or fill material into a water of the United States, including wetlands. Due to the extensive nature of this alternative, compliance with Section 404 would be difficult, and perhaps impossible. Therefore, implementation of a dredging alternative may require this ARAR to be waived. Provisions of the Clean Air Act could also apply to dispersion of PCB from drying sediments in the CDFs. Clean Air Act requirements could likely be met through covering.

Since the Kalamazoo River Site is designated as a CERCLA site, permits are not required for on-site activities; however, the substantive applicable requirements of Federal and State regulations would need to be met. With respect to administrative feasibility, negotiations with affected landowners to use and develop access areas would be required.

Long-Term Effectiveness and Permanence – Alternative 5

- The risk reduction benefits of dredging would not be realized until after the end of the 25-year project, plus the additional years needed for post-remedial natural recovery to further reduce residual surface sediment PCB concentrations.
- Dredging technology has several inherent limitations that reduce its ability to create a clean sediment surface and reduce risks. These limitations are discussed in detail in Appendices D and E, which present data and observations from many other sediment removal projects.

Implementation of Alternative 5 would be both effective and reliable over the long-term as a means of accelerating the reduction of exposure to PCB at this Site. Much of this reduction in exposure is primarily attributable to the bank stabilization efforts, and continuing natural attenuation. While implementation of this alternative would serve to remove PCB-containing materials throughout the Site, it is estimated to take 25 years to complete the dredging with little ultimate benefits above those achieved through bank stabilization, which could be achieved in four years. The long-term risk of exposure or uptake by fish and/or transport of the dredged PCB residuals will lessen over time following dredging, as the post-remedial natural attenuation processes further reduce the surficial sediment PCB concentrations. However, upstream sources of PCB could cause recontamination of downstream surface sediments in some reaches if the upstream sources are left uncontrolled.

The limited reductions in long-term PCB exposure conditions attributable to dredging are themselves based on optimistic projections regarding the effectiveness of dredging to achieve target residual levels in the sediment. The optimistic assumption that dredging will achieve those target levels is not supported by experience at other sites, as described in Appendix D. The information in Appendix D presents the results of dredging efforts to remove PCB-containing sediments at sites throughout the United States, and demonstrates that removal efficiencies, measured as the percentage of average surficial PCB concentration remaining following removal efforts, ranges from 75% (or a net increase in the average surficial sediment PCB concentration of 75%) to less than 2% (or a net reduction in the average surficial concentration of over 98%). The median value, which is most representative of the combined experience seen during the execution of full-scale hydraulic dredging operations intended to remove PCB-containing sediments, is 27%, or a 73% reduction in the average pre-dredging surficial PCB concentrations.

With final dredging depths ranging from 24 to 66 inches throughout the Site, the current benthic community would be completely eliminated. Elimination of the benthic substrate and community would also have a significant negative impact on the fish community. The length of time it would take for the benthic and fish communities to recover following 25 years of extensive dredging is unknown.

Reduction of Toxicity, Mobility, or Volume through Treatment – Alternative 5

Treatment is not a significant component of Alternative 5 and, thus, the reduction of toxicity, mobility, or volume of the PCB-containing sediment would be minimal. There would be some treatment of PCB contained in the water discharged from the CDFs, since these PCB would likely be destroyed through incineration (i.e., re-generation of the activated carbon portion of the water treatment system). Removal of PCB-containing sediment would reduce the volume of sediment in the river, but that same volume of material would simply be transferred to the three CDFs constructed in communities near the Site. It is also important to note that the volume of PCB-containing sediment would be increased over the short-term within the CDFs as a result of bulking during the dredging process.

Short-term Effectiveness – Alternative 5

> - The existing benthic community throughout the river would be completely destroyed. Recovery time is unknown.
> - Even with aggressive mitigation efforts, there will be negative impacts and PCB releases to surface water during dredging.
> - Significant areas of wetlands and terrestrial habitats would be destroyed or isolated to construct temporary access roads along the 50-mile length of the Site.
> - Approximately 4,600,000 truck trips would be necessary to haul materials to and from the Site; the likelihood of accidents and injuries due to this traffic is high.

The short-term effects of dredging in the river include significant destruction of areas used to construct access points, significant alteration of substantial benthic community, release of PCB to the water column during implementation of dredging, and disruption of recreational and other traffic in the river. There would be short-term impacts to water quality throughout the dredging program. While hydraulic and support controls (e.g., silt curtains) would be implemented to minimize PCB releases to the water column during dredging activities, these controls would not be entirely effective in preventing releases. For example, while silt curtains aid in containment of suspended solids during dredging activities, they are generally not effective in controlling either the dissolved phase release of PCB or the flow of solids and PCB underneath the bottom of the silt curtain near the sediment-water column interface. In addition, silt curtains provide no control for the migration of solids and PCB in the vicinity of the operating dredge where the potential for dredge-related redistribution of PCB to surficial sediments is the highest. In addition, equipment required for movement/set-up of silt curtains may disturb PCB-containing sediment. Daily monitoring of PCB migration due to dredging activities would be required to assist in minimizing releases of PCB.

Alternative 5 will unavoidably increase PCB transport in the Kalamazoo River during implementation. While dredging operations would be conducted as reasonably practical to control resuspended sediment losses, the sediment dredging production rates assumed here, and which are necessary for the project to the implementable, cannot be achieved without the loss of some resuspended sediment to downstream areas. Furthermore, the loss of dissolved-phase PCB is inherently less controllable than particulate phase losses. Dissolved phase PCB losses would originate from:

- Desorption from resuspended sediment;
- Desorption from more highly contaminated bed sediments exposed within the areas being dredged; and
- Liberation of sediment pore waters as the sediment bed is broken up by the mechanical actions of the debris clearing and dredging operations.

The challenge for dredging in attempting to achieve RRO 2 is that it would attempt to reduce annual transport rates (approximately 26 kg/yr in 1994) that are a very small and diminishing fraction of the total inventory (26,000 kg) in the channel sediments that would be dredged. Even small percentage losses of that inventory during dredging operations will substantially increase transport during implementation of the remedy. It can be seen that even losses as small as 1 percent[2] over 25 years could cause increased transport of the magnitude of transport measured during the RI [(0.01 x 26,000 kg)/25 years or approximately 10 kg/yr).

Under this program, bank stabilization eliminating the remaining major continuing external source of PCB to the Site would begin approximately 8 years after the start of construction, and would not be complete until 14 years after the start of construction. The construction of the bank stabilization components could not begin until dredging is complete in the former impoundments, to avoid destabilizing the banks by removing sediments at the toe of the slope.

Removal of all PCB-impacted sediment from the Site through dredging would completely eliminate the current benthic community. With final dredging depths ranging from 24 to 66 inches, the sediment substrate that supports the current benthos will be completely eliminated and may never return to conditions reflective of the current environment. This process would have significant negative impacts on the overall ecosystem for some period of time. The length of time it would take for the benthic community to recover from the effects of dredging, and the extent of that eventual recovery, are unknown. Similar negative impacts on the fish community may be experienced as well.

Another significant impact is the destruction of wetland and terrestrial resources associated with the construction of additional access roads along the banks of the entire Site. These impacts include large amounts of wetland and upland habitat destruction, habitat fragmentation, species isolation, and production of additional "edge" habitat. These effects would be especially pronounced in areas where the riparian corridor is narrow and may serve as an important wildlife corridor between areas of more dense vegetation. Impacts would be less significant in areas containing extensive and high quality riparian corridor habitat. Birds, mammals, reptiles, and amphibians are all likely to be impacted from the habitat destruction from this alternative. Benthic feeding and piscivorous species would be further impacted by the degradation to the aquatic habitat and communities that comprise their prey base. These impacts are discussed in detail in the *Supplement to the Kalamazoo River RI/FS*.

During dredging operations, remediation workers and the community at-large would not be exposed to PCB levels that present unacceptable health risks if appropriate health and safety practices (OSHA 29 CFR 1910.129) are followed at

[2] Monitoring of PCB losses from two recent dredging demonstration projects on the Fox River in Wisconsin showed increased PCB transport downstream from the project areas to be approximately 3.5 to 14 percent of the PCB mass removed (BBL, 2000a; FRRAT, 2000).

the Site through implementation of a Site-specific HASP. However, land-based traffic would increase substantially (e.g., total of over 4.6 million truck trips) and persist for the lengthy duration of the project. This increased traffic increases the likelihood of accidents and would elevate levels of exhaust fumes and noise.

As presented in Appendix G, a total of over 12 million worker-hours is estimated to be required to complete the river-wide dredging and bank stabilization. Based on the estimated worker-hours and general accident statistics for labor categories relevant to those expected to be involved with the implementation of this remedial alternative, the chance of at least one worker fatality during this remedy is 90 percent.

There would also be off-site transportation risks associated with the trucking of clean fill materials to the Site. As presented in Appendix H, this alternative will require the transportation of approximately 29,000,000 cy of material, representing approximately 4.6 million truck trips. Based on an evaluation of national traffic accident data, approximately 217 accidents are predicted for off-site transportation of material necessary for this remedy. This corresponds to a 40 percent chance of a transportation-related fatality during implementation of the dredging remedy, and an estimated 18 collision-related injuries.

Implementability – Alternative 5

The availability of necessary equipment and specialists is not expected to pose an implementability concern.[3] Construction of the three large CDFs will require significant amounts of local borrow material, sand, and final cap materials.

Dredging is a technology typically used to remove large quantities of sediments from shipping lanes in waterways. However, the ability or technical feasibility of dredging to achieve environmental restoration objectives is highly questionable based on the results of the limited number of sediment remediation projects conducted to date. Appendix D presents an overview of experiences and problems encountered by others in applying dredging technologies to achieve target levels of risk reduction and numerical sediment

- The probability that dredging technology will achieve environmental cleanup standards is questionable at best. See Appendix D for case studies and details.
- The water treatment units would employ proven technologies, but the variability of both water generation rates and composition of dredged materials may cause treatment delays that would slow the dredging schedule.
- The dredging schedule necessary to complete the project in 25 years – 6 days a week, 24 hours a day, 10 months a year – would be disruptive and potentially unacceptable to the community.

[3] Simultaneously employing a larger number of dredges (e.g., 5 or more) would greatly increase the potential for downstream impacts associated with dredging and would require a dramatic increase in the number and size of CDFs and WTFs.

cleanup goals. Dredges have been inconsistent in their ability to achieve remedial objectives, and often require multiple dredging passes in an attempt to do so. Alternative 5 could pose implementability concerns relative to the need for additional remedial action; for example, if the targeted dredging depths are unable to achieve cleanup criteria, additional remedial action may be necessary consisting of additional dredging passes. This could create further bank stability problems as the toes of the stream banks become lowered further.

The magnitude and duration of Alternative 5 pose a number of implementability concerns, aside from the short-term impacts described above. To complete the dredging over a relatively reasonable time period, dredging activities are proposed to occur six days a week, 24 hours per day for over a 10-month construction season. The noise and disruption caused by such activities will likely draw strong opposition from the local community.

Administration of a 25+ year construction program will likely span many changes in personnel, contractors, and local social and political climates, as well as evolving technologies and regulations. Siting and land acquisition for three 135 to 770+ acre CDF locations to contain PCB-contaminated sediments could prove difficult, even in a rural setting. Community receptivity presents an implementability concern for a project of this magnitude. The significant destruction of land and water habitats to support the CDFs and the dredging activities would likely have an impact on community receptivity.

A CDF is a commonly-constructed technology for dewatering and containing dredged sediments. The introduction of PCB into a CDF adds an additional degree of complexity, and will likely require the use of synthetic liners, drainage layers, surface capping, and groundwater monitoring wells, which are not typically a part of CDF design. While PCB typically adsorbs tightly to soil and sediment particles, and it is not likely that PCB would migrate from the CDF, the liners may be required to satisfy regulatory design requirements.

The water treatment unit processes of flocculation, sedimentation, multimedia filtration, and activated carbon adsorption are all established technologies, even for treatment rates in the range of 3 to 20 MGD. However, the variability of water generation rates and composition, coupled with the anticipated low effluent discharge standards (especially problematic during the last few years of operation, when increased flow rates to the CDFs will coincide with the CDFs approaching design capacity, while having less buffering ability to attenuate large quantities of water) would likely cause problems to arise that could result in schedule delays. As a result, it may be necessary to slow down the dredging operations to accommodate water treatment processes as the CDFs begin to approach storage capacity.

The availability and capacity of off-site treatment, storage, and disposal services is not expected to be of concern as long as construction of CDFs is a part of the remedy. If this large quantity of dredged material were expected to be disposed in municipal or commercial landfills, a lack of available capacity would pose a substantial implementability concern.

Coordinating with local agencies could pose an implementability concern for negotiating access rights and acquiring or renting staging areas at the many tentatively identified sites along the river. Since the Site is designated as a CERCLA site, permits are not required for on-site activities. However, the substantive, applicable requirements of Federal and State regulations would need to be met. Permits may be required, however, for construction of the three CDFs, since it is uncertain whether or not they will be located on or within the designated CERCLA site.

Cost – Alternative 5

The estimated capital and O&M costs to implement Alternative 5 are approximately $2,552,230,000 and $66,215,000, respectively, for a total cost of $2,618,445,000 (+50%/-30%). This results in an estimated present worth cost to implement dredging and disposal as discussed in Alternative 5 of approximately $839,747,000. A breakdown of the estimated costs for implementing Alternative 5 is presented in Table 4-5.

Inside Section 5 – Comparative Analysis of Remedial Alternatives

Do the alternatives achieve the Remedial Response Objectives?

- Alternatives 3-5, all entailing former impoundment bank stabilization, would successfully achieve the primary RRO: *Reduce PCB concentrations in Kalamazoo River fish to acceptable levels in terms of human health and ecological risk.* Alternative 3 would meet this RRO in the shortest amount of time since it controls the largest ongoing source of PCB to the river most rapidly. Alternatives 1 and 2 may not achieve this objective due to the effects of continued PCB loading from the former impoundment banks.

- All five alternatives would achieve RRO 2 *(Reduce water column transport of dissolved or particle-bound PCB to Lake Michigan)*, and, again Alternative 3 meets the goal the fastest in the least destructive manner.

- Only Alternatives 3, 4, & 5 would achieve RRO 3 *(Reduce or control PCB sources to the Kalamazoo River)* since source control is not a part of alternative 1 or 2.

Are the alternatives "implementable?"

While all five alternatives are theoretically implementable, alternatives 4 and 5 present serious barriers due to their vast scope – no comparable capping or dredging projects have ever been attempted in the United States. The protracted time frame of these alternatives (40 years for Alternative 4 and 25 years for Alternative 5) as well as the significant burdens on the community (increased truck traffic, lost use of the river, noise concerns due to 24-hour work days six days a week) and the river (widespread, possibly permanent habitat disruption and destruction) are not justified by greater risk reduction relative to Alternative 3.

How will we know if the remedy is successful?

Alternatives 2, 3, 4, and 5 all have a monitoring component, which means that the health of the river will be tracked after the alternative is implemented to see if PCB levels in Kalamazoo River fish are declining to the point where consumption advisories can be removed. PCB levels in the surface water and surface sediment will also be tracked, so a complete picture of river health would emerge over time.

After an extensive review of each alternative as well as a comparative analysis, Alternative 3 emerged as the remedy that was effective, implementable, cost-effective, and afforded the best overall protection of human health and the environment.

5. Comparative Analysis of Remedial Alternatives

5.1 Introduction

> The next step toward selecting a preferred remedy for the Kalamazoo River is to compare all five alternatives within the context of each of the nine NCP criteria. Based on tradeoffs among the alternatives, a preferred alternative emerges and is recommended for development of the Proposed Plan for the Kalamazoo River.

In Section 4, each of the five remedial alternatives for the Site was evaluated in detail with respect to seven of the nine NCP criteria in accordance with NCP requirements. The two remaining modifying criteria (Agency and community acceptance) are typically evaluated following preparation of the FS and Proposed Plan. In this section, a comparative analysis of all remedial alternatives is conducted with respect to each of the seven NCP criteria. As noted previously, these criteria include:

- Overall protection of human health and the environment;
- Compliance with ARARs;
- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume through treatment;
- Short-term effectiveness;
- Implementability; and
- Cost.

The following alternatives, as described in Section 4, are being evaluated:

- Alternative 1: No Further Action;
- Alternative 2: Institutional Controls and Monitoring;
- Alternative 3: Bank Stabilization at the Former Impoundments, Monitored Natural Attenuation, and Institutional Controls;
- Alternative 4: River-Wide Capping of Submerged Sediments, Bank Stabilization at the Former Impoundments, Institutional Controls, and Monitoring; and
- Alternative 5: River-Wide Dredging of Submerged Sediments with Upland Confined Disposal, Bank Stabilization at the Former Impoundments, Institutional Controls, and Monitoring.

On a comparative basis, each of the following subsections briefly reviews the primary advantages and disadvantages of each alternative with regard to the seven NCP criterion under consideration. In addition, the relative performance of each alternative in achieving the criteria is represented graphically according to the chart provided at the right. Based on these analyses, Section 6 presents a recommended remedial alternative for the Site.

Scoring the Alternatives		
To provide a brief summary of how each alternative measures up to the NCP criteria, a relative "score" is assigned according to the legend shown here. These scores are then compared at the end of Section 5 to provide an overview of the best overall remedy for the Site		Fully meets criterion
		Mostly meets criterion
		Partially meets criterion
		Does not meet criterion

5.2 Overall Protection of Human Health and the Environment

This criterion addresses the overall effectiveness of an alternative in protecting human health and the environment (i.e., achieving the identified RROs) by reducing PCB exposure and associated potential risk. Recall that the primary RRO for the Site is:

RRO 1: Reduce PCB concentrations in Kalamazoo River fish to acceptable levels in terms of human health and ecological risk.

Alternative	RRO1 Score	RRO2 Score	RRO3 Score
1			
2			
3			
4			
5			

Ancillary RROs for the Site are as follows:

RRO 2: Reduce water-column transport of dissolved or particle-bound PCB to Lake Michigan; and

RRO 3: Reduce PCB loading to the Kalamazoo River.

The following discussion compares the potential of the remedial alternatives to achieve the RROs as a measure of overall protection of human health and the environment.

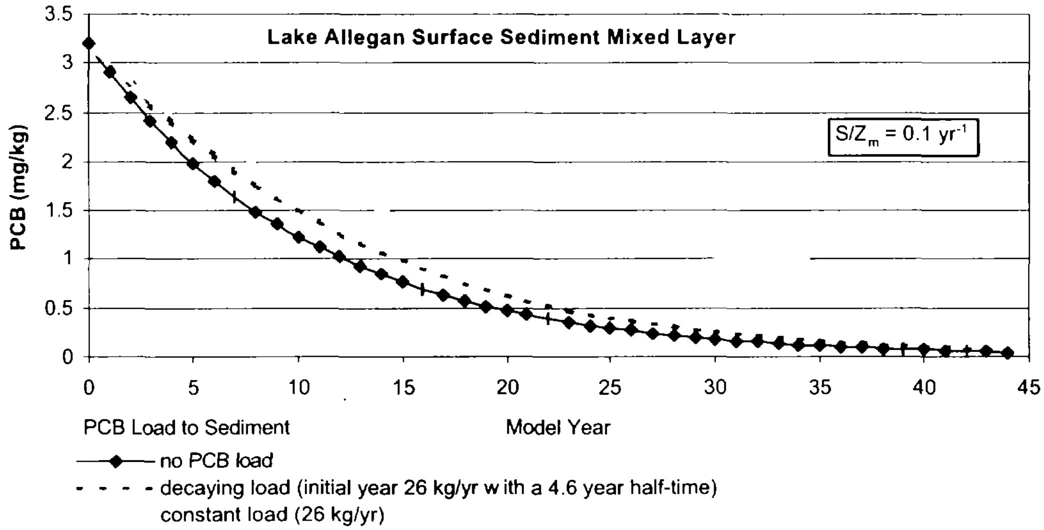
RRO1: Reduce PCB concentrations in Kalamazoo River fish to acceptable levels in terms of human health and ecological risk.

The degree of reduction in fish PCB concentration is the key determinant of the overall effectiveness and level of protectiveness of human health and the environment provided by each alternative. Natural attenuation processes occurring at the Site will continue to diminish PCB bioavailability and exposure over time, which will lead to reductions of PCB concentrations in fish and surface waters. This will occur and would be relied upon exclusively to reduce PCB levels in fish and water under Alternatives 1 and 2. As indicated by the systems analysis presented previously (RI report Section 5.3 and Section 2 of this report), natural attenuation processes also will be responsible for most of the reduction of PCB concentrations in fish and surface waters under the "action" alternatives (Alternatives 3 through 5) as well. The basic reason for this is the relatively rapid rate of natural attenuation. This is evident from the simple mass balance for the Lake Allegan mixed-layer of surface sediments, which represents approximately two-thirds of the area of the sediment surface at the Site.

> - All five alternatives would achieve RRO 1 and reduce PCB exposure and resulting PCB concentrations in fish and other media.
> - Alternative 3 would achieve this RRO more rapidly than other alternatives.
> - The largest portion of the risk reduction beyond natural attenuation offered by Alternatives 3 through 5 is attributable to bank stabilization.

The following figure presents estimates of PCB concentration in the mixed layer of surface sediments in Lake Allegan for conservative values of sediment deposition rate and mixing layer thickness ($S/Z_m = 0.1$ year^{-1}). This is a conservative prediction because a faster intrinsic rate of decrease ($S/Z_m = 0.2$ year^{-1}) can be supported from observations of Lake Allegan sediment and the empirical analysis of PCB levels in Lake Allegan fish yields faster rates. The initial (time=0) concentration in this figure is that estimated from the 1993/1994 sediment cores. The figure indicates that if PCB loading to the sediments continued to decline at the rates estimated from observations of PCB levels in the water column of the Kalamazoo River (-0.15 year^{-1} or 4.4 year half time), then PCB levels in mixed layer sediments, and therefore fish, would be halved in under 10 years. Furthermore, even if PCB loading to the sediments was found at rates associated with 1993/1994 conditions (i.e., no source reduction), PCB levels would still be reduced by 50% in approximately 13 years. Considering the 25 to 40 year time frames necessary to implement alternatives such as capping (Alternative 4) and dredging (Alternative 5), it is evident that most of the future reduction in surface sediment and fish PCB concentrations will be attributable to natural attenuation processes even if such projects are undertaken.

If external loading of PCB to the system from sources such as the banks of exposed sediments in the MDNR-owned former impoundments continues at present levels, the PCB levels in surface sediment and fish will reach a steady-state concentration and will not diminish further. This general pattern is seen in the uppermost curve in the figure below.



The extent to which external loading of PCB maintains elevated concentrations of PCB in surface water and fish is not clear from this level of analysis. However, given the comparable magnitude of PCB loading from the bank to estimates of PCB transport and the relatively low level of PCB necessary to remove all fish consumption advisories, it is reasonable to expect that if bank loading of PCB did not diminish, then PCB levels in surface sediment would reach a steady-state concentration above an unacceptable level. As previously illustrated, a magnitude of 0.4 to 0.8 mg/kg PCB in surface sediment can be reasoned for this steady-state concentration in Lake Allegan. By simple proportionality among fish and surface sediment PCB concentrations observed in 1993 in Lake Allegan, this would suggest a range of average PCB levels in carp fillets and smallmouth bass fillets that would still require some fish consumption advisories.

The above figure illustrates relatively little additional benefit to PCB load reduction beyond the rates that have been observed by monitoring PCB transport in the Kalamazoo River since the mid 1980s. Considering the speed and ease with which the bank loading PCB source can be controlled, and the potentially high proportion of its contribution to sustaining PCB levels in surface sediments throughout much of the system in the future, Alternative 3 may be more protective than Alternatives 1, 2, and 5, which either do not address bank loading of PCB (i.e., Alternatives 1 and 2) or would not control bank loading until some later date (i.e., Alternative 5).

RRO 1 would be achieved by implementing Alternatives 3 through 5. However, the extent to which these reductions would occur over a 40-year time-frame varies between alternatives. If PCB loading from the former impoundment riverbanks does not diminish over time, Alternatives 1 and 2 may not achieve RRO 1. In general, Alternatives 3 through 5 exhibit faster reductions in fish PCB levels over time than Alternatives 1 and 2. Bank stabilization alone (Alternative

3) provides a significant reduction in fish PCB levels as compared to natural attenuation (Alternatives 1 and 2). Because Alternatives 4 and 5 implement river-wide remedial measures in conjunction with bank stabilization it is important to gage the benefits of the capping and dredging components of Alternatives 4 and 5 beyond those of bank stabilization alone. Incremental reductions incurred through the two river-wide remedial actions (i.e., Alternatives 4 and 5) in addition to that provided by bank stabilization are minimal.

Additionally, the level of effectiveness predicted for river-wide dredging (Alternative 5) is based on the optimistic assumption that dredging would achieve lower residual PCB concentrations in the sediment. This assumption does not account for the redistribution of PCB-containing sediment that is suspended during dredging and then redeposits on the dredged surface to become the new surficial sediment.

RRO 2: Reduce water-column transport of dissolved or particle-bound PCB to Lake Michigan

As discussed in the RI and this FS, natural attenuation processes are ongoing at the Site. These processes result in the continued decrease in PCB bioavailability and exposure over time, thereby resulting in decreasing PCB levels in surficial sediment. As such, the potential for water-column transport of dissolved or particle-bound PCB to Lake Michigan is diminished, and RRO 2 would be met by all alternatives.

> - All five alternatives would achieve RRO 2 and reduce PCB transport to downstream areas and Lake Michigan.
> - The bank stabilization component of Alternatives 3 through 5 would cut off the largest remaining external source of PCB to the river and, therefore, reduce transport.
> - Both dredging and, to a lesser extent, capping (Alternatives 4 and 5) would increase sediment and PCB transport during implementation because of the disruption to the sediment bed by the dredge or, in the case of capping, by other construction equipment.

As noted in Section 4, the degree to which these reductions occur varies between alternatives. Bank stabilization alone (Alternative 3) provides a significant reduction in PCB transport over the long term as compared to natural attenuation (Alternatives 1 and 2). Because Alternatives 4 and 5 implement river-wide remedial measures in conjunction with bank stabilization, it is important to gauge and consider the benefits of the capping and dredging components of Alternatives 4 and 5, beyond those of bank stabilization. The incremental reductions incurred through the two river-wide remedial actions (Alternatives 4 and 5) beyond that provided by bank stabilization alone would appear to be small according to the limited systems analysis permitted by the MDEQ to be included in this report. These incremental benefits occur after an extended implementation period, during which natural attenuation processes, accelerated by the elimination of the PCB loads from the banks of former impoundments through the stabilization activities, will have acted to significantly reduce water column PCB concentrations.

As stated previously, the level of effectiveness predicted for river-wide dredging (Alternative 5) is based on the optimistic assumption that dredging would achieve lower residual PCB concentrations in the sediment, and does not account for the redistribution of PCB-containing sediment that is suspended into the water column during dredging and transported downstream or redeposited on the dredged surface to become the new surficial sediment.

RRO 3: Reduce PCB loading to the Kalamazoo River

> - **Alternatives 3, 4, and 5 would achieve RRO 3 by controlling the erosion of PCB-containing sediment deposits within MDNR's three former impoundments.**

The banks of the three MDNR-owned former impoundments are the predominant remaining source of PCB to the Kalamazoo River. As such, all alternatives with a bank stabilization component will satisfy RRO 3. Therefore, Alternatives 3 through 5 would meet RRO 3, while Alternatives 1 and 2 would not. However, the overall protectiveness of all alternatives could be limited by the continuing inputs of PCB to the Site from upstream and other likely uncontrolled sources.

5.3 Compliance with ARARs

Alternative	Score
1	
2	
3	
4	
5	

This criterion assesses whether a given alternative would comply with chemical-specific, location-specific, and action-specific ARARs and possibly other criteria, advisories, and guidance, as appropriate.

Although natural attenuation is continuing to reduce PCB water column levels, none of the alternatives would be expected to achieve the Michigan Part 31 PCB Water Quality Standard for protection of human health (0.026 ng/L) or the standard for protection of wildlife (0.12 ng/L). A waiver would be required for this ARAR under all five alternatives. As noted in Section 2, even snowpack in the northernmost portion of Michigan or Lake Superior exceeds these levels by a factor of 15 to 70 times. Beyond natural attenuation, the largest improvements in water-column PCB levels are achieved by implementing Alternatives 3 through 5. These improvements are predominantly attributable to bank stabilization alone (Alternative 3) with river-wide capping and dredging (Alternatives 4 and 5) having only slight, if any, theoretical long-term improvements in water-column PCB levels over those of bank stabilization. Therefore, implementation of Alternative 3 would have the most rapid improvement on water quality.

Additional chemical-specific ARARs applicable to Alternative 5 include portions of the Clean Water Act for discharges from wastewater treatment facilities. These facilities would be designed to meet those requirements as specified under the Michigan Water Resources Commission Act. TSCA would be applied as appropriate where removed sediments exceed 50 mg/kg PCB.

> ➢ Although all alternatives would reduce PCB levels in fish, water, and surface sediments over time, none of the alternatives are expected to achieve the Michigan Water Quality Standard for PCB within a reasonable time frame. Thus, a waiver would be required to implement any alternative.

Since Alternatives 1 and 2 do not involve any additional Site activities, action- and location-specific ARARs do not apply. Several federal and state action- and location-specific ARARs require that permits be obtained for activities included in Alternatives 3 through 5. These ARARs include the federal Clean Water Act, the State of Michigan Wetland Protection Act, the State of Michigan Inland Lakes and Streams Act, the State of Michigan Soil Erosion and Sedimentation Control Act, both the federal and state OSHA standards, USEPA Executive Order 11988, USDOT transportation and handling requirements, and the Clean Air Act. While Section 121(e) provides that on-site response actions may proceed without obtaining permits, the substantive permit requirements still apply.

Alternatives 4 and 5 are extremely intrusive Site-wide alternatives that would have a profound impact on habitats and the environment during implementation. It is possible that disruption or destruction of identified endangered species and/or their habitats could occur during implementation of Alternatives 4 and 5, although precautionary measures would be undertaken in compliance with related ARARs to the extent practicable. Implementation of Alternatives 4 and 5 also may present difficulty with regard to the substantive requirements of Section 404 of the Clean Water Act (33 U.S.C. 1344), which regulates discharge of dredged or fill material into waters of the United States, including wetlands. Due to the extensive nature of Alternatives 4 and 5, compliance with Section 404 during their implementation would be difficult, and perhaps impossible, due to the scale of the impacts to the ecosystem that this Section is intended to prevent. It may, therefore, become necessary for this ARAR to be waived.

Construction of CDFs as part of Alternative 5 would likely occur outside of the geographic bound of the Superfund Site, and a number of permits and regulatory approvals will be required prior to construction. ARARs related to permitting and siting requirements associated with locating CDFs in area communities could present difficulties due to opposition from residents and local interests.

5.4 Long-term Effectiveness and Permanence

This criterion considers the effectiveness of a given alternative with respect to reducing exposure and potential risk and its ability to maintain protectiveness over time. Effectiveness is directly related to the degree of risk reduction achieved through implementation of an alternative, as indicated by the effect of the alternative on PCB levels in fish.

Alternative	Score
1	□
2	□
3	■
4	■
5	■

For all alternatives, risk reduction would be achieved through ongoing natural attenuation of PCB concentrations in fish, as well as in surface sediment and the water column. The RI data indicate that fish PCB levels have been declining since at least the mid-1980s to the point where the most recent monitoring data justify substantially relaxing current fish consumption advisories. Alternatives 2 through 5 include a long-term monitoring component that would facilitate tracking the effectiveness of the actions taken under these alternatives. It is noteworthy that Kalamazoo River fisheaters studied under the current set of fish consumption advisories did not exhibit blood PCB levels that, when controlled for the effects of age, were elevated above the non-fisheating reference group. Exposure to fish consumers would be reduced with the additional reduction expected to occur under Alternatives 1 through 5.

Under Alternatives 1 through 4, and to a lesser extent 5, maintenance and operation of all dams along the Kalamazoo River by their owners in compliance with law would retain the PCB-containing sediments behind the dams and within the impoundments over the long term.

> ➢ Source control, institutional controls, natural recovery, monitoring, and maintenance are all important components of Alternatives 3 through 5 that would contribute to the long-term effectiveness of these alternatives.

The erosion control/bank stabilization measures within the former impoundments, a component of Alternatives 3 through 5, would mitigate the ongoing migration of PCB-containing exposed sediments into the water column. As these banks are the most significant remaining source of PCB to the system, addressing these areas is crucial to the protectiveness of any alternative considered at the Site. The bank stabilization would be designed and maintained to remain physically stable and to effectively isolate the PCB-containing bank sediments, thereby accelerating the rate of recovery over the long term.

Compared to Alternative 3, the additional long-term protection afforded by implementation of river-wide dredging or capping as part of Alternatives 4 and 5, respectively, is minimal. Reductions in exposure achieved by Alternatives 4 and 5 are primarily attributable to bank stabilization efforts. Implementation of bank stabilization efforts (Alternative 3) is anticipated to be complete in 4 years. Implementation time for Alternative 4 is estimated at 40 years, while

Alternative 5 is estimated at 25 years. When the implementation time required for the river-wide component (capping or dredging) of Alternatives 4 and 5 is factored in, bank stabilization efforts are just as effective when comparing reductions achieved in the year following completion of the construction required by Alternatives 4 and 5.

With respect to long term protection, the physical processes of natural attenuation have been shown to be resistant to reversal by the forces of extremely high river floors as evident by the analyses in the RI Report. The deposition and burial of PCB in Lake Allegan is the major process determining the fate of PCB in both higher energy channel sediments upstream of Lake Allegan as well as in the sediments of Lake Allegan. The flows required to scour sediment in Lake Allegan are well above the 100-year flood flow.

Introduction of river-wide capping (Alternative 4) also raises concerns of decreased water depth in currently shallow areas. Adding sufficient cap/armor material to meet all of the design criteria could alter flood flows and would likely reduce storage capacity within the Kalamazoo River system.

5.5 Reduction of Toxicity, Mobility or Volume through Treatment

Alternative	Score
1	□
2	□
3	□
4	□
5	□

This criterion considers expected reductions in toxicity, mobility, or volume of chemical-containing materials through treatment as a result of implementing an alternative. Except for a minor component of Alternative 5 (which includes destruction of PCB in effluent from dewatered, dredged material via incineration during regeneration of the activated carbon portion of the water treatment system), none of the alternatives considered include active treatment.

5.6 Short-term Effectiveness

Alternative	Score
1	□
2	□
3	■
4	□
5	□

This criterion considers short-term adverse impacts to human health and the environment related to construction during implementation of the remedial alternative. Considerations include environmental impacts of construction to humans and biota, and the protection of on-site workers and the neighboring community during construction and implementation of the remedy.

Alternatives 1 and 2 do not involve active remediation, therefore, short-term risks due to implementation are not a concern. It should be noted, however, that the absence of fish consumption advisories in Alternative 1 could hypothetically increase human consumption of fish, thereby potentially increasing certain short-term risks.

> ➢ The short-term impacts of Alternative 3 would be far less and more localized than the more intrusive and longer term alternatives involving river-wide capping or dredging.
>
> ➢ Alternatives 4 and 5 would disrupt or destroy habitat across a vast area, interfere with recreational enjoyment of the river, and would pose significantly greater new risks to workers and the community throughout the long construction period and as a consequence of millions of dumptruck trips to haul materials to and from the Site.

The short-term effects associated with bank stabilization of the former impoundments (components of Alternatives 3 through 5) include habitat disruption or alteration of habitat in certain areas along the affected banks from constructing access roads and stabilizing the impacted banks. Though realized under Alternative 3, these effects would impact the environment on a substantially longer temporal scale under Alternatives 4 and 5. Implementation of Alternatives 4 and 5 would also cause ecological impacts to terrestrial and aquatic ecosystems on a much larger spatial scale. It is expected that recovery from the short-term effects of bank stabilization will be realized due to the proposed primary restoration measures.

Although the immediate impacts to biota and their aquatic, wetland, and upland habitats are expected to be deleterious and significant, these impacts will be limited in spatial scale and are not expected to be permanent. Based on the restorative measures included in the bank stabilization remedial alternative, significant long-term degradation of ecological resources is not expected. The primary long-term impacts will be the prevention of natural processes such as bank undercutting, stream meandering and impacts to biota that burrow into stream banks.

Aside from the short-term effects of bank stabilization, Alternatives 4 and 5 would cause significant destruction of both the formerly impounded areas and those areas used to construct access points, the loss of the benthic community in 2,900 acres of river bottom, potential releases of PCB resuspended to the water column during implementation, and the disruption of recreational activities and boat traffic in the river. The most significant impacts to wetland and terrestrial resources would be associated with the removal of mature trees from the construction of access roads along the banks of the entire Site. These impacts include large amounts of wetland and upland habitat destruction, habitat fragmentation, and species isolation.

The short-term effects on the area community would also be substantially more pronounced for the river-wide alternatives (capping and dredging). Truck traffic would increase significantly during implementation, increasing exhaust fumes, the noise level near the work area, and, the potential for vehicular accidents. Approximately 35 to 65 times more truck trips would be required for Alternatives 4 and 5 than would be required for bank stabilization. Appendix H discusses the predicted numbers of vehicular accidents and associated injuries and fatalities from the implementation of Alternatives 3 through 5. These are summarized in the table below.

Summary of Estimated Number of Collisions and Collision-Related Fatalities and Injuries Associated with Off-Site Transport of Site-Related Materials

	Alternative 3 Bank Stabilization	Alternative 4 River-wide Capping	Alternative 5 River-wide Dredging with Upland Confined Disposal
Estimated Number of Accidents	3.3	176	217
Estimated Number of Collision-Related Fatalities	$5.8x10^{-3}$	$3.1x10^{-1}$	$3.9x10^{-1}$
Estimated Likelihood of Collision-Related Fatalities	1 in 170 chance	1 in 3 chance	1 in 3 chance
Number of Estimated Collision-Related Injuries	$2.7x10^{-1}$	15	18

During implementation of Alternatives 3 through 5, appropriate controls (e.g., a silt containment system and daily monitoring) would be utilized to mitigate or contain short-term effects. While silt curtains aid in containment of suspended solids, the curtains would not prevent all releases in the vicinity of remedial operations. In addition, equipment required for movement and set-up of various silt curtains may disturb and suspend PCB-containing sediment. These effects would be most prevalent in alternatives targeting submerged sediments river-wide (Alternatives 4 and 5). Based on experience obtained at other sites (see Appendices D and E), dredging (Alternative 5) is expected to provide increased short-term risks relative to capping (Alternative 4). The disruptive nature of dredging would resuspend PCB-contaminated sediments into the water column, making PCB more bioavailable to fish. While silt curtains are somewhat helpful in mitigating this impact, they cannot prevent soluble constituents from escaping. USEPA (2000a) observes that "Poor short-term effectiveness can weigh significantly against an option, and can in fact, result in an alternative being rejected as unprotective if adverse impacts cannot adequately [be] mitigated. For sediment remedies that involve dredging, the issue of resuspension of contaminants during implementation is considered as part of this criterion. There are many parties who believe that resuspension of particles during dredging cannot be adequately controlled, and as such, dredging should not be considered as a remedy."

During the implementation, construction, and monitoring associated with all remedial alternatives, workers and the community would be protected through implementation of a site-specific HASP. Appendix G discusses the risks to workers that would be expected during the implementation of Alternatives 3 through 5. These risks are summarized in the table below.

Summary of Worker Risk Estimates

Remedial Alternative	Risk of at Least One Fatality
Alternative 3 Bank Stabilization	2%
Alternative 4 River-Wide Capping	38%
Alternative 5 River-wide Dredging with Upland Confined Disposal	88%

In summary, the short-term impacts of Alternative 3 will be felt over a total construction period of 4 years. In stark contrast, the "short-term" impacts of the river-wide dredging and capping alternatives will extend over decades, causing significant disruption of ecosystem processes. Alternative 3 also shuts off the remaining major external source of PCB to the Site sooner than in Alternatives 4 and 5.

5.7 Implementability

Alternative	Score
1	■
2	■
3	■
4	□
5	□

This criterion evaluates the implementability of an alternative with respect to both technical and administrative feasibility, including the availability of appropriate services and materials. Technical feasibility includes the ability to construct and operate the technology, the reliability of the technology, and the ability to effectively monitor the technology. Administrative feasibility includes the ability to obtain applicable permits or meet permit requirements, and the degree to which any coordination with other government agencies can be achieved. From USEPA's (2000a) perspective, "monitored natural attenuation, in-situ capping, and dredging are all implementable alternatives. However, site-specific conditions will usually make one alternative more feasible than others. For remedies that include dredging as a component, it is important to consider the availability of treatment and/or disposal facilities for the contaminated sediment [because] lack of disposal facilities is an important factor to consider. Also, it may be difficult to dredge over hardpan or bedrock, around large objects such as logs and boulders, and around piers and bridge pilings."

Remedial components that include institutional controls, monitoring, and bank stabilization (as considered in Alternatives 2 and 3) are expected to be technically feasible. Implementation of river-wide Alternatives 4 and 5 would prove challenging due primarily to the unprecedented size and duration of implementation.

Average water depths in various segments of the Kalamazoo River vary between two and seven feet. As such, placement of capping materials (Alternative 4) in the shallower areas would significantly alter the natural hydraulics of the river, including a substantial decrease in flood storage capacity. Presentation of the natural hydraulics of the river would force compromises in the design of the cap (i.e., reduction of cap thickness) that would in turn reduce the long-term effectiveness of Alternative 4.

> ➢ Based on numerous administrative and technical feasibility considerations, Alternative 3 offers the greatest net benefit in terms of implementability concerns. For example:
> - Construction methods are conventional and reliable.
> - Construction will take only about 4 years.
> - Access requirements are limited primarily to state land.
> - Institutional controls are not new or complex.
> - No new landfills are needed.
> - Ecological and economic disruption is minimized.

The ability or technical feasibility of dredging (as considered in Alternative 5) to achieve low level residual PCB concentrations in sediment is highly questionable based on the results of the limited number of remedial dredging projects studied to date. As discussed in Appendix E, the presence of rocks and debris, mixing of PCB-containing sediment into underlying or surrounding sediment, limitations and inconsistencies of removal efficacy, and resuspension (and resettlement) of sediment are all factors which may impede the technical feasibility of dredging (Alternative 5). For example, if dredging to targeted depths does not achieve low enough levels, additional dredging passes may need to be attempted. This could create or exacerbate bank stability as the toes of the riverbanks throughout the Site are lowered even further.

Additional implementability concerns associated with alternatives addressing sediments on a river-wide basis (Alternatives 4 and 5) include limited access from the Trowbridge Dam to the Allegan City Dam, several train crossings, many one-way streets in the developed areas, and weight limitations on certain roads and bridges. Factors limiting the implementability of to dredging and capping alternatives (e.g., heavy traffic volume, geotextile placement, etc.) would be exacerbated by the implementation of river-wide Alternatives 4 and 5 due to their substantial time of implementation requirements.

Institutional controls and monitoring included as part of Alternatives 2 through 5 are not expected to present a concern with regard to administrative feasibility. These same alternatives also include a comprehensive dam maintenance program which assumes that the MDNR will undertake dam maintenance and additional source control actions, and that the other dam owners will comply with the law, performing required inspections and maintenance.

Provided the substantive requirements of otherwise applicable permits are met, permits are not required for on-site (i.e., in-river and contiguous areas) activities at a CERCLA site. Construction of the CDFs required by Alternative 5 would likely occur outside of the geographic bound of the CERCLA site. Accordingly, a number of permits and regulatory and community approvals may be required prior to CDF construction.

In general, it is expected that the construction equipment and personnel necessary to implement these alternatives would be available in sufficient supply. It should be recognized, however, that the availability of certain types of materials required for alternatives requiring bank stabilization and cover of submerged sediments may be limited. This consideration may impact Alternative 3 and, to an incrementally higher degree, Alternative 4. With regard to Alternative 5, the availability of disposal services and capacity is not expected to be a concern provided that construction and siting of CDFs is a component of the remedy. Should disposal in municipal or commercial landfills become a necessity, the lack of available capacity would pose a substantial implementability concern due to the large quantity of dredged material to be generated through implementation of the alternative.

5.8 Cost

> ➢ Alternative 3 is the most cost effective alternative. Alternatives 4 and 5 are much more expensive but do not offer a greater degree of risk reduction and carry a much higher degree of short-term negative impacts.

The total present worth costs of the alternatives, listed in decreasing order, are as follows: Alternative 5 ($839M); Alternative 4 ($298M); Alternative 3 ($38.7M); Alternative 2 ($0.7M); and Alternative 1 ($0). A summary of the total present worth cost and total cost for each alternative is provided below and details are provided in Tables 4-1 through 4-5. These cost estimates have been developed with an accuracy of +50% to –30%. Final cost estimates would be developed and refined through the remedial design process following the selection of a Recommended Remedy.

Summary of Remedial Alternative Costs

Alternative	Total Cost	Total Present Worth Cost
1	0	0
2	$1,186,000	$653,000
3	$73,186,000	$40,679,000
4	$1,734,382,000	$300,494,000
5	$2,618,455,000	$839,747,000

5.9 Summary

In consideration of the comparative advantages and disadvantages of the five alternatives as described in this section and as shown in the summary figure below, Alternative 3 would deliver the greatest overall net benefits and, on balance, provide the greatest level of overall protection of human health and the environment.

Alternative	Overall Protection of Human Health and the Environment			Compliance with ARARs	Long-Term Effectiveness	Reduction of Toxicity Mobility & Volume Through Treatment	Short-Term Effectiveness	Implement-ability	NPV Costs (Total Costs)
	RRO1	RRO2	RRO3						
1 - No Further Action	▣	□	□	□	□	□	□	■	$0 ($0)
2 - Institutional Controls and Monitoring	▣	□	□	□	□	□	□	■	$0 7M ($1 2M)
3 - Bank Stabilization at the Former Impoundments, Monitored Natural Attenuation and Institutional Controls	■	■	■	□	■	□	■	■	$40.7M ($73.2M)
4 - River-Wide Capping of Submerged Sediments, Bank Stabilization at the Former Impoundments, Institutional Controls, and Monitoring	■	■	■	□	■	□	□	□	$300M ($1.7B)
5 - River-Wide Dredging of Submerged Sediments with Upland Confined Disposal, Bank Stabilization at the Former Impoundments, Institutional Controls, and Monitoring	■	▣	■	□	■	□	□	□	$840M ($2.6B)

- ■ Fully meets criterion
- ▣ Mostly meets criterion
- □ Partially meets criterion
- □ Does not meet criterion

Regarding performance against the seven NCP criteria considered at this time, Alternative 3 would provide the following primary benefits:

- *Overall protection of human health and the environment* – Alternative 3 is expected to reduce human and ecological risk by decreasing PCB concentrations in fish, reduce PCB transport, and address the most significant remaining source of PCB loading to the Kalamazoo River, thereby achieving all three RROs. Moreover, Alternative 3 is expected to provide the greatest overall protectiveness in terms of minimizing short-term construction-related risks while optimizing long-term effectiveness relative to the river-wide capping or dredging alternatives.

- *Compliance with ARARs* – While none of the alternatives are expected to achieve the Michigan water quality standards (which would require a waiver of that ARAR), the localized scale of Alternative 3 has the advantage of being more technically and administratively feasible, which suggests a greater probability of compliance with all other ARARs relative to the larger and more complex capping and dredging alternatives.

- *Long-term effectiveness and permanence* – Because natural attenuation processes have already demonstrated effectiveness in reducing PCB bioavailability and exposure over the past two decades, Alternatives 4 and 5 are not expected to provide a significantly greater level of long-term effectiveness relative to the additional source control and continuance of natural recovery provided under Alternative 3. As discussed in the RI report, the long-term performance and permanence of natural attenuation in the Kalamazoo River is not expected to be disrupted by rare and extreme events such as storms, floods, or high winds. In addition, the extensive long-term monitoring and maintenance program would track the effectiveness of the remedy and thus assure continued performance over the long term.

- *Reduction of toxicity, mobility, and volume through treatment* – None of the alternatives include a significant treatment component, as large-scale treatment of low-concentration sediments is unnecessary and impracticable both technically and administratively.

- *Short-term effectiveness* – The PCB transport and risk reduction benefits of Alternative 3 are expected to accrue quickly in that mitigation of the PCB transport from eroding riverbanks in the former impoundments will immediately increase the rate and effectiveness of natural attenuation. An additional clear advantage of Alternative 3 is that it would avoid the serious increased risks to workers and the community generated by the protracted schedules, scale, and complexity of the capping and dredging alternatives (e.g., requiring movement of millions of cubic yards of material in millions of truck trips over local roadways for 25 or more years).

- *Implementability* – Alternative 3 is the most technically and administratively feasible and reliable remedy that would still provide an adequate level of overall protectiveness. Design and construction would take just 6 years, as opposed to the 25- and 40-year time frames required for the dredging and capping alternatives. Natural attenuation is expected to be effective in reducing risks, yet it does not require disruption or destruction of the entire riverbed and surrounding habitat, nor does it require siting and construction of disposal facilities near local communities.

- *Cost* – Alternative 3 is the most cost-effective remedy considering the level of risk reduction provided per level of effort and expense. Alternatives 1 and 2 cost less but would not provide as high a level of risk reduction.

Conversely, Alternatives 4 and 5 cost much more but would fail to provide significantly greater risk reduction than Alternative 3.

The relative advantages and expected performance of Alternative 3 are discussed in greater detail in Section 6 of this FS and Section 4 of the *Supplement to the Kalamazoo River RI/FS*.

Inside Section 6 – Preferred Remedy

Stabilizing the banks in the former impoundments, monitoring natural attenuation, and implementing institutional controls is a feasible, reliable, cost-effective remedy that will quickly provide a high degree of overall protection to human health and the environment.

Removal of dams on the Hudson River in New York and the Kalamazoo River created unstable riverbank sources of PCB. Stabilization of eroding riverbanks along the Upper Hudson River was successful in controlling this source of PCB. Similar measures are proposed for the Kalamazoo River to eliminate PCB transport from the eroding banks of the three former impoundments.

Benefits of the preferred remedy

- Reliably achieves all remedial objectives without the large-scale negative impacts of other more intrusive alternatives.
- Construction can be completed in just 4 years, with limited short-term impacts.
- Increases rates of natural recovery in biota, surface sediment, and surface water.

Why stabilize the banks?

The riverbanks in the former impoundments are the most significant ongoing source of PCB to the river. Removing the banks as a source of PCB will speed natural recovery processes and reduce risk. The stabilization project will use proven, reliable technologies and conventional construction techniques. Other alternatives that cost significantly more and take far longer to implement than the 4 years planned for bank stabilization do not reduce risks significantly faster or better than the natural recovery processes already at work in the river.

Monitoring will ensure effectiveness

- By law, every five years the agencies will be required to answer the question, "Is this remedy working?" If it is not working, additional steps will need to be taken.
- Aggressive and comprehensive long-term monitoring will continue for at least 30 years.
- Fish, surface water, and surface sediment samples will be collected to assess natural recovery rates.

6. Preferred Remedy

6.1 Preferred Remedy – Alternative 3

Based on RI findings, risk evaluations, and a comparative analysis of NCP criteria, Alternative 3 (i.e., stabilization of the banks in MDNR's former impoundments, monitored natural attenuation, institutional controls, and additional investigations of external sources) is expected to provide the greatest level of overall net environmental benefit relative to other alternatives, without corresponding destruction of the existing ecosystem. As indicated by numerous scientific and engineering analyses conducted during the RI/FS, Alternative 3 would reduce risks and quickly deliver a high degree of overall protection of human health and the environment through implementation of a remedy that is feasible, reliable, and cost-effective relative to other alternatives.

Primary Benefits of Alternative 3

- Remedy will reduce risks and achieve all three remedial objectives:
  - RRO1: reduce PCB levels in fish
  - RRO2: reduce PCB transport
  - RRO3: control PCB sources
- Source control (bank stabilization) will increase the rate and effectiveness of natural recovery.
- A comprehensive long-term monitoring program will track effectiveness of remedy.
- Short-term risks due to construction and habitat destruction are minimized.
- Design and construction will take just 4 years and use proven, reliable methods.
- Alternative 3 is a cost-effective remedy that delivers the greatest overall net benefits to the community and Kalamazoo River watershed.

Alternative 3 would achieve the primary RRO and reduce potential risks associated with consumption of Kalamazoo River fish by humans or wildlife through timely mitigation of the most significant external source of PCB remaining within the watershed—the eroding banks of former sediment deposits in the former Plainwell, Otsego, and Trowbridge impoundments. The two ancillary RROs would also be met, since Alternative 3 would reduce source loading to the Kalamazoo River and ultimately reduce PCB transport to Lake Michigan.

PCB fate and transport analyses conducted during the RI indicate that the bank erosion pathway may contribute from 10 to 100 kg of PCB to the river each year. This represents a significant source of PCB to bioavailable surface sediments within the former impoundments and downstream reaches. Indeed, as other external sources of PCB diminish or are controlled, uncontrolled PCB loading from the former impoundment banks will continue over time, increasing in relative contribution of PCB to the watershed. By controlling this large source, Alternative 3 would increase the rate of natural attenuation already observed in Kalamazoo River sediment, water, and fish. The uncontrolled loading from the former impoundment banks is sustaining higher levels of PCB in the River. The KRSG will continue to develop and apply a comprehensive model of sediment (and PCB) fate and transport for the Kalamazoo River. This model, along with additional empirical data recently collected (see the *Supplement to the Kalamazoo River RI/FS*), will further clarify the role of these banks and the extent that Alternative 3 will accelerate river recovery and risk reduction. To address other potential ongoing external sources of PCB to the system, Alternative 3 includes efforts by the MDEQ and others to investigate and monitor uncontrolled external sources such as certain tributaries, POTWs, industrial stormwater effluents, storm sewer effluents, and various other known or unknown sources of PCB.

Beyond source control measures in the three former impoundments, Alternative 3 relies upon natural attenuation of PCB in sediment, surface water, and fish as an effective means of risk reduction. Multiple lines of evidence analyzed during the RI/FS demonstrate that natural attenuation processes observed and measured in the Kalamazoo River (e.g., dispersion from high energy areas, sediment mixing, and gradual burial of PCB in low energy areas) are the key factors in having reduced PCB availability for downstream transport and biological exposure over the past two decades. As progressively cleaner sediments enter Lake Allegan over time, the older, higher PCB concentration surface sediments are mixed with the incoming lower concentration sediments and gradually sequestered in deeper layers of the sediment bed. Natural attenuation processes have resulted in the transfer and burial of PCB to the Lake Allegan and Allegan City impoundments, which have accumulated a total of 79% of the PCB in the river channel today. RI data support this observation; the arithmetic average PCB concentration in the top 2 inches of Lake Allegan sediment in 1994 was approximately 3.2 mg/kg, while the average in the underlying 4 inches of sediment was approximately 6.6 mg/kg.

As availability of PCB in surface sediments has decreased, so have PCB concentrations in surface water. As reported in the RI, mid-1980s PCB data from the MDNR showed water column loading of approximately 12 kg/yr at River Street, increasing to 61 kg/yr at Plainwell and 140 kg/yr at the Allegan City Impoundment (M-222). In marked contrast, estimated 1994 loading, while similar at River Street, decreased to 28 kg/yr at Plainwell and 26 kg/yr at the Allegan City Impoundment (and 25 kg/yr downstream of Lake Allegan). PCB concentrations in fish also have declined over a similar time period with fish tissue concentrations (smallmouth bass and carp) decreasing approximately 5.9% per year in Plainwell and 10% per year in Lake Allegan. These observations and trends are supported by more recent data and analyzed in the *Supplement to the Kalamazoo River RI/FS*.

By relying on natural recovery processes that are active in the system and have been shown through measurement and modeling to be effective in reducing PCB concentrations, exposure, and potential risk, Alternative 3 also avoids the negative impacts of the river-wide capping or dredging alternatives (Alternative 4 and 5), such as extremely long and complex construction projects and widespread destruction of riverine habitat. Although bank stabilization will cause localized short-term impacts to affected terrestrial and aquatic habitats, requiring recolonization and recovery of the wetland complex within the three former impoundments, capping or dredging will take decades to complete and potentially reverse the observed two-decade-long decreases in PCB concentrations in surface sediments. This will increase exposure and risks in the short term in addition to increasing construction-related risks as well, with a much greater probability of construction or transportation accidents involving workers or local residents.

While Alternative 3 is being implemented, consumption advisory institutional controls would need to remain in place to reduce human exposure that may pose unacceptable risks. Indeed, these advisories would have to remain in effect during implementation of any of the remedial alternatives. Based upon fish trend monitoring data, natural recovery has decreased PCB levels in fish to the point where current advisories can be relaxed substantially or removed in some reaches of the Kalamazoo River (see RI Report Section 5). This includes general population advisories for smallmouth bass from the entire Kalamazoo River. Similarly, advisories for bass consumption by sensitive populations (e.g., children and women of child-bearing age) can be relaxed to less restrictive levels between Morrow Dam and Lake Allegan Dam (see RI Report Section 5). Monitoring and adjustment of consumption advisories is technically and administratively feasible to implement.

An additional administrative requirement of Alternative 3, common to all alternatives, would be the necessary waiver of the Michigan water quality standard ARAR due to the inability of any natural or technological intervention to achieve compliance with the standard in the near term.

The comparative evaluation of alternatives shows that Alternative 3 would be reliable. Stabilization of the former impoundment banks features proven, reliable technologies and straightforward, conventional construction techniques. The effectiveness of the remedy is expected to be reliable and permanent over the long term, which will be assured through periodic maintenance of the bank stabilization measures and monitoring of natural recovery trends in sediment, water, and fish.

Finally, the comparative evaluation of alternatives shows that Alternative 3 would be cost-effective. At a total cost of over $70 million, Alternative 3 is cost effective relative to other more costly, complex, and intrusive alternatives (e.g., Alternatives 4 and 5) that, despite added cost and scope, would not deliver greater levels of risk reduction or short- and long-term effectiveness. The large-scale river-wide alternatives, despite their vast scope, would not perform significantly better or faster than the source control and natural recovery components of Alternative 3 alone (see the *Supplement to the Kalamazoo River RI/FS* for additional discussion).

Simply put, Alternative 3 is expected to deliver the greatest overall net benefits to local communities and the Kalamazoo River watershed through timely implementation of a project that will invest nearly $70 million in effective source control risk reduction measures and long-term monitoring of remedy performance.

6.2 Monitoring the Effectiveness of the Preferred Remedy

Empirical data generated during the RI indicate that natural attenuation has already been effective in reducing potential risks associated with PCB transport and biological exposure in the Kalamazoo River. Data also support the conclusion that this natural recovery will continue to be effective in reducing risks in the future and, in combination with the source control measures of Alternative 3, achieve the RROs. To verify this conclusion through time and ensure that risks are reduced to acceptable levels, Alternative 3 includes a comprehensive long-term monitoring program to track the effectiveness of the proposed remedy. The program would coincide with the periodic 5-year reviews of a remedy as required by CERCLA. Under Alternative 3 natural recovery will continue to effectively reduce PCB bioavailability in sediments and thus decrease concentrations in fish and the water column without the high level of uncertainty in the effectiveness of capping or dredging, and without the high costs and short-term risks of those intrusive alternatives.

Long-term Monitoring Program

USEPA (2000a) requires that long-term monitoring protocols be specified in any natural attenuation remedy to detect changes in contaminant concentrations over time. Alternative 3 includes a comprehensive, long-term monitoring and maintenance program to track the effectiveness of the remedy and ensure its long-term reliability. Components include:

- Maintenance of the bank stabilization measures implemented in the former impoundments to ensure long-term performance of source control.
- Fish sampling every 3 to 5 years to monitor decreases in PCB levels and to provide data for relaxation or removal of consumption advisories.
- Surface water sampling every 5 years to monitor decreases in PCB levels and decreases in PCB loading and downstream transport.
- Sediment sampling every 5 years to monitor decreases in bioavailable PCB levels.
- CERCLA requires that Superfund Site remedies be reviewed every 5 years to monitor status and ensure that the remedy is performing as designed. The monitoring program will provide important data for these periodic reviews.

The long-term monitoring program would consist of periodic sampling and analysis of fish, surface water, and surface sediment in several reaches of the Kalamazoo River to track the performance of natural recovery and the degree to which the MDCH fish consumption advisories are still appropriate. For fish, these two objectives require two separate fish sampling approaches, one for adult fish and another for yearling fish. To assess the progress of natural recovery in reducing the availability of PCB to fish, monitoring of yearling fish as composite samples is desirable because measurements would be less variable at a given time than measurements of PCB levels in adult fish. Low variation in these measurements aids in the statistical analysis of changes in bioavailability over relatively short periods. Adult fish samples for assessment of the fish consumption advisories would be processed following standard MDCH protocols to obtain samples representative of a standard edible portion (fillet). All whôle-body composite and fillet samples would be analyzed to measure PCB concentration and percent lipid.

Performance standards, for the remedy to be gauged by, will be developed as part of the remaining work at the Site. The remaining work includes continued field investigation downstream of Lake Allegan under the direction of the MDEQ as well as the proposed inclusion of additional data and information that have been collected by the KRSG into a future revision of the document. The development of performance standards will likely entail quantitative assessment of the expected river-wide response in fish PCB levels to external source control and establishment of milestones for future PCB levels in fish to be achieved by the remedy.

Target fish species selected for both sampling approaches (e.g., carp and smallmouth bass) would remain consistent with previous fish sampling efforts completed during the RI (1993 and 1997) and during supplemental sampling in 1999. Consistent with past efforts, carp and bass samples would be collected from six different reaches of the river every 3 years for advisory monitoring purposes (about 200 samples) and every 5 years for natural recovery monitoring (about 60 samples), for a total of 30 years. After each round of sampling, an assessment report would be prepared to document trends, verify remedy effectiveness in risk reduction, and make recommendations regarding how and when consumption advisories should be modified.

Similarly, approximately 180 sediment samples and 190 surface water samples would be collected and analyzed every 5 years for a period of 30 years. Samples of surface sediments from six existing transects (approximately 5 samples each) would be analyzed for PCB (Aroclor basis and some congener-specific), TOC, and grain size. The water column would be sampled in 12 pre-established locations and during typical baseflow and high flow periods. Water samples would be analyzed for general water quality parameters, TSS, TOC, and PCB (Aroclor basis and some congener-specific).

To ensure the comparability of these data, samples will be collected in accordance with the existing approved *Field Sampling Plan* (BBEPC, 1993d), *Health and Safety Plan* (BBEPC, 1993b), and *Quality Assurance Project Plan* (BBEPC, 1993a). A detailed *Long-Term Monitoring Plan* would be developed (including the establishment of performance criteria) prior to commencement of the monitoring program. The monitoring results would be presented and discussed in a brief report compiled after each monitoring period. The monitoring program is robust and would cost approximately $13.9 million over the 30-year period, as detailed further in Table 4-3. In addition to the benefits of directly monitoring the effectiveness of natural recovery, the data generated through this program would be ideally suited for periodic updates and future enhancements to mathematical models developed for the Kalamazoo River, as described in the *Supplement to the Kalamazoo River RI/FS*, all of which would help improve the overall quality, use, and enjoyment of the resource.

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engineers & scientists

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Tables

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TABLE 2-1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
POTENTIAL FEDERAL AND STATE ARARs AND TBCs

Law/Regulation/Guidance	Citation	Description	Potential ARAR/TBC	Rationale
FEDERAL CHEMICAL-SPECIFIC ARARs AND TBCs				
Clean Water Act (CWA)	33 USC 1314 40 CFR 131.36(b)(1)	National recommended criteria for surface water quality.	ARAR	Applicable to remedial activities conducted at the Site.
USEPA Office of Emergency and Remedial Response EPA 540/G-90/007	OSWER Directive 9355.4-01	Guidance on remedial actions for Superfund sites containing PCB.	TBC	May be used as a guideline for handling PCB-containing sediment/soil.
CWA-Water Quality Guidance for the Great Lakes System	40 CFR 132 33 USC 1251 et. seq.	Establishes water quality criteria for Great Lakes states.	ARAR	Applicable to remedial activities conducted at the Site.
USFDA-PCB in food for human consumption	21 CFR 109	Specifies temporary tolerance for residues of PCB as unavoidable environmental or industrial contaminants in edible portions of fish.	TBC	May be used as guidance for actions involving fish consumption advisories.
STATE CHEMICAL-SPECIFIC ARARs AND TBCs				
Michigan Natural Resources and Environmental Protection Act (NREPA) (Part 31 of Act 451, Part 4)	R323.1041-1117	Establishes water quality requirements for surface waters in the State.	ARAR	Applicable to remedial activities conducted at the Site.
FEDERAL ACTION/LOCATION-SPECIFIC ARARs AND TBCs				
CWA - Toxic Pollutant Effluent Standards	40 CFR 129	Establishes effluent standard for toxic compounds including PCB (40 CFR 129.105). Applies to discharges to navigable waters.	ARAR	Applicable for remedial alternatives that would include discharge of water to the river.
Federal Power Act of 1920	16 USC 791a et. seq. 18 CFR 1-149	Authorizes the Federal Energy Regulatory Agency (FERC) to issue licenses for hydro-power dams.	TBC	Remedial alternatives involving alteration of dam operations would require consideration of existing permits.

TABLE 2-1
(Continued)

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
POTENTIAL FEDERAL AND STATE ARARs AND TBCs

Law/Regulation/Guidance	Citation	Description	Potential ARAR/TBC	Rationale
FEDERAL ACTION/LOCATION-SPECIFIC ARARs AND TBCs (Continued)				
CWA - Discharge to Waters of the United States	33 CFR 320-330 40 CFR 122 40 CFR 403-404 40 CFR 230 40 CFR 136 33 USC 1341, 1344	Establishes site-specific chemical limitations and performance standards designed to protect surface water quality. Types of discharges regulated under the CWA include discharge to surface water, indirect discharge to a POTW, and discharge of dredged or fill material into U.S. waters.	ARAR	May be relevant and appropriate for remedial alternatives involving treatment and/or discharge of water or capping/armoring materials to the river.
Rivers & Harbors Act	33 CFR 320-330	Prohibits unauthorized obstruction or alteration of any navigable water in the U.S. (dredging, filling, cofferdams, piers, etc.).	ARAR	Remedial activities may have to be conducted in such a way as to avoid obstruction or alteration of the river.
	33 CFR 322 33 USC 403	Requirement for permits affecting "navigable waters of the U.S."	ARAR	If excavation or capping activities are performed, the substantive requirements of the Act must be met for work affecting "navigable waters of the United States."
USEPA - two executive orders: 11990 - Protection of Wetlands 11988 - Floodplain management.	40 CFR 6.302 40 CFR 6, App. A	Requires federal agencies, where possible, to avoid or minimize adverse impacts of federal actions upon wetlands/floodplains and enhance natural values of such.	TBC	Executive orders affect any work conducted in floodplains or wetlands.
Toxic Substances Control Act (TSCA)	40 CFR 761.120 - 761.135	Spill cleanup policy establishes cleanup criteria for spills after 5/4/87; soil cleanup levels: unrestricted access - 10 mg/kg, restricted access - 25 mg/kg. Guides treatment of PCB.	TBC	Although the presence of PCB at the Site is due to some releases after 5/4/87, the cleanup criteria may still be considered when evaluating remedial alternatives, especially given that most of the releases occurred much earlier.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
POTENTIAL FEDERAL AND STATE ARARs AND TBCs

Law/Regulation/Guidance	Citation	Description	Potential ARAR/TBC	Rationale
FEDERAL ACTION/LOCATION-SPECIFIC ARARs AND TBCs (Continued)				
TSCA	40 CFR 761	Provides regulations for storage and disposal of materials containing PCB, and for discharges of water containing PCB to navigable waters.	ARAR	Applicable for PCB-containing materials that are removed from the Site.
Clean Air Act	40 CFR 52	Establishes filing requirements and standards for constituent emission rates in accordance with National Ambient Air Quality Standards (NAAQS).	TBC	To be considered for remedial alternatives that include removal of sediment/soil.
OSHA - Hazardous Waste Operations and Emergency Response	29 CFR 1910.120	Establishes health and safety requirements for clean-up operations at NPL sites.	ARAR	Site is listed on NPL.
Fish and Wildlife Coordination Act	16 USC 661 et seq. 33 CFR 320-330	Requires that any federal agency that proposes to control or modify a body of water first consult with USFWS and state wildlife agency.	TBC	To be considered for capping and dredging alternatives.
National Historical Preservation Act	15 CFR 470 et seq.	Preservation of historic properties and landmarks.	TBC/ARAR	Becomes ARAR if activities will affect historic properties or landmarks in or near the Site.
Endangered Species Act	50 CFR 402 16 USC 1531 et seq. 50 CFR 200	Requires federal agencies to ensure that the continued existence of any endangered or threatened species and their habitats will not be jeopardized by a site action.	TBC	Activities may disrupt or disturb endangered species.
USDOT Placarding and Handling	49 CFR 171	Transportation and handling requirements for materials containing PCB with concentrations of 20 mg/kg or more.	ARAR	This would apply to alternatives where sediment/soil are removed and transported from the Site.

TABLE 2-1
(Continued)

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
POTENTIAL FEDERAL AND STATE ARARs AND TBCs

Law/Regulation/Guidance	Citation	Description	Potential ARAR/TBC	Rationale
STATE ACTION/LOCATION-SPECIFIC ARARs AND TBCs				
Michigan Water Resources Commission Act (Part 31 of Act 451, Parts 8 and 21)	R323.1201-1221 R323.2101-2195	Establishes effluent standards in accordance with federal WPCA and CWA.	ARAR	Applicable for alternatives involving discharge of water to the river.
Michigan NREPA (Part 201 of Act 451)	R324.20101-20140	Establishes rules specifying environmental response, risk assessment, remedial action, and site cleanup criteria.	ARAR	Applicable to remedial activities conducted at the Site.
Michigan Hazardous Waste Management Act (Part 111 of Act 451)	324.11101 - R324.11152	Establishes requirements for hazardous waste generators, transporters, and treatment/storage/disposal (TSD) facilities.	TBC	The Site is not a TSD facility nor a generator of hazardous wastes, although certain portions of the regulations may be useful as a means of determining handling/transportation requirements.
Michigan Geomacre-Anderson Wetland Protection Act (Part 303 of Act 451)	324.30301 - 324.30323	Establishes the rules regarding wetland uses and the permit application process for protection of state wetland areas.	ARAR	For certain remedial alternatives, these regulations may limit potential work and/or storage areas.
Michigan Inland Lakes and Streams Act (Part 301 of Act 451)	R324.30102-30104	Regulates dredging or filling of lake or stream bottoms.	ARAR	For certain remedial alternatives, activities may be restricted by these regulations.
Michigan Soil Erosion and Sedimentation Control Act (Part 91 of Act 451)	R323.1701-1714 R324.9112	Establishes rules prescribing soil erosion and sedimentation control plans, procedures, and measures.	ARAR	If work is conducted in off-Site floodplain areas, a soil erosion and sedimentation control plan may be required to perform earth changes.
Michigan Water Resources Commission Act (Part 31 of Act 451)	R323.2204-R323.2207	Establishes the rules regarding water and wastewater discharge provisions for the nondegradation of groundwater quality, uses of groundwater.	ARAR	If remedial alternatives involve discharge of waters or waste to groundwater or the ground.

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
POTENTIAL FEDERAL AND STATE ARARs AND TBCs

Law/Regulation/Guidance	Citation	Description	Potential ARAR/TBC	Rationale
STATE ACTION/LOCATION-SPECIFIC ARARs AND TBCs (Continued)				
Michigan Wastewater Reporting Regulations	R299.9004	Requires discharge reporting on the part of any wastewater discharger other than of sanitary sewage to a sewer system.	TBC	Applicable to any alternatives involving discharge of wastewater.
Michigan Water Resources Protection Act	R324.3101-3111	Establishes permit requirements for alteration of floodplains, discharges to surface waters.	ARAR	Applicable if remedial alternatives involve construction in floodplains.
Michigan Occupational Safety and Health Act (MIOSHA-Act 154)	Act 154 of 1974 as amended (parts 1-49)	Establishes the rules for safety standards in the workplace.	ARAR	For certain remedial alternatives, activities may be restricted by these regulations.
Michigan Air Pollution Act (Part 55 of Act 451)	R336.1101-2706	Establishes rules prohibiting the emission of air contaminants in quantities that cause injurious effects to human health, animal life, plant life of significant economic value, and/or property.	TBC	For certain remedial alternatives, dust emissions may need to be monitored.
Michigan Dam Safety Rules (Part 315 of Act 451)	R324.31501-31529	Establishes rules regarding construction, repair, alteration, removal, abandonment, or reconstruction of dams.	ARAR	ARAR for any remedial alternative that would entail the actions described to the left.
Michigan Endangered Species Act (Part 365 of Act 451)	R324.36501-36507	Establishes rules to provide for conservation, management, enhancement, and protection of species either endangered or threatened with extinction.	TBC	For certain remedial alternatives, activities may disrupt or disturb endangered species.
Michigan Solid Waste Management Regulations (Part 115 of Act 451)	R324.11501-11550 R299.4401-4454	Establishes rules for solid waste disposal facilities.	ARAR	Would apply to an alternate involving landfill or CDF construction.

TABLE 2-2

ALLIED PAPER INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
AREAS POTENTIALLY SUBJECT TO REMEDIATION

River Reach	Area (acres)	Volume of PCB-Containing Sediment (cy)	Length (miles)	Slope (ft/mile)	Average Water Depth (ft)	Average River Width (ft)
Morrow Lake	1,000	2,541,000	3.3	--	6	2,500
Morrow Dam to Portage Creek	112	58,000	4.8	2.1	3	196
Portage Creek to Main Street, Plainwell	331	341,000	15.2	2.6	3.5	174
Main Street, Plainwell to Plainwell Dam (Former Plainwell Impoundment)	44	53,000	1.9	4.6	3.7	197
Plainwell Dam to Otsego City Dam	96	224,000	1.7	0.88	2.5	450
Otsego City Dam to Otsego Dam (Former Otsego Impoundment)	83	191,000	3.4	4.3	3.8	200
Otsego Dam to Trowbridge Dam (Former Trowbridge Impoundment)	131	263,000	4.7	1.5	5	248
Trowbridge Dam to Allegan City Line	190	258,000	7.2	2.3	4.4	196
Allegan City Line to Allegan City Dam	127	417,000	1.9	1.3	3.8	655
Allegan City Dam to Lake Allegan Dam	1,649	5,143,000	9.8	1.2	6.7	1,500
Portage Creek	7	23,050	2.0	1.9	2.3	32
Totals (w/o Morrow Lake)	2,770	6,971,050	52.6			

Notes:
Estimates are subject to change based on receipt of 2000 data.
Average widths represent the actual water widths for the respective transects excluding islands or sandbars.
Volume of PCB-containing sediment based on depth of sediment in which PCB were detected in analyzed cores, and weighted by sediment texture (fine or coarse) and frequency of PCB detection.
Reaches Morrow Dam to Portage Creek; Portage Creek to Main Street, Plainwell; and Trowbridge Dam to Allegan City Line are free flowing.
Reaches Plainwell Dam to Otsego City Dam; Allegan City Line to Allegan City Dam; and Allegan City Dam to Lake Allegan Dam include current impoundments.

TABLE 3-1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY LIST OF POTENTIAL REMEDIAL TECHNOLOGIES AS PRESENTED IN THE RI/FS WORK PLAN

Potentially Applicable Remedial Technology	Process Description	Potentially Applicable Media[1]	Potentially Applicable Constituents[2]
1.0 In-Situ Containment/Control			
1.1 Capping	Isolation and containment of constituents by placement of layer(s) of physical materials (e.g., granular materials, clay, concrete, asphalt, synthetic materials, grout or cement-filled geotextile mats, bentonite/synthetic membrane pads) over areas containing constituents.	Sediments, soils, residuals	Organics, Inorganics
1.2 Erosion Control	Prevention of erosion (and subsequent transport) of contaminated materials by velocity control or barrier mechanisms, or by reimpoundment of exposed areas containing constituents.	Sediments, surface water, soils	Organics, Inorganics
1.3 Hydraulic Containment	Use of physical barriers (e.g., slurry walls, sheet piles, injected screens, grout curtains) to prevent the movement of contaminated groundwater.	Groundwater	Organics, Inorganics
2.0 In-Situ Treatment			
2.1 Immobilization	Immobilization of constituents of concern in a solid mass (monolith), formed either by injecting and mixing an immobilization agent into the media or by melting the media.	Sediments, soils, residuals	Organics, Inorganics
2.2 Extraction	Removal of constituents of concern from media by extraction wells, steam, or vacuum, followed by treatment of constituents.	Sediments, soils, residuals	Organics (based on technology process), Inorganics
2.3 Biodegradation	Degradation of media constituents utilizing microorganisms in either an aerobic or anaerobic environment.	Sediments, soils, residuals, water	Various organics (based on technology process)
2.4 Chemical	Use of chemical agents to change the nature of the constituents through oxidation, reduction, or neutralization.	Sediments, soils, residuals, water	Various organics and inorganics (based on technology process)
2.5 Thermal	Heating of media with radio frequency waves to vaporize and thermally destroy constituents.	Sediments, soils, residuals	Organics
3.0 In-situ Support Technologies			
	Technologies which enhance the effectiveness of in-situ treatment technologies including groundwater zone dewatering to enhance fluid or vapor-flow.	Sediments, soils, residuals	Organics, Inorganics
4.0 Removal			
4.1 Dredging	Removal and transportation of bottom sediments.	Sediments, residuals	Organics, Inorganics
4.2 Excavation	Physical removal of waste constituents by typical excavation equipment under "dry" conditions.	Sediments, soils, residuals	Organics, Inorganics
4.3 Groundwater Removal	Collection of contaminated groundwater for treatment by wells or drains.	Groundwater	Organics, Inorganics
5.0 Disposal			
5.1 Off-site	Disposal of media in an existing permitted TSCA/RCRA or solid waste landfill facility.	Sediments, soils, residuals	Organics, Inorganics
5.2 On-site	Disposal of media in a CDF (upland or in-water) or newly-constructed permitted TSCA/RCRA or solid waste landfill facility.	Sediments, soils, residuals	Organics, Inorganics

(See notes on page 2.)

TABLE 3-1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY LIST OF POTENTIAL REMEDIAL TECHNOLOGIES AS PRESENTED IN THE RI/FS WORK PLAN (cont'd)

Potentially Applicable Remedial Technology	Process Description	Potentially Applicable Media[1]	Potentially Applicable Constituents[2]
5.3 Groundwater	Disposal of treated or untreated water through discharge to surface water, discharge to POTW, or reinjection underground.	Water	Organics, Inorganics
6.0 Upland Treatment			
6.1 Immobilization	Immobilization of constituents of concern by mixing of excavated/removed material with immobilization agents to form a monolith which is subsequently disposed.	Sediments, soils, residuals	Organics, Inorganics
6.2 Extraction	Removal of constituents of concern from media for subsequent management via chemical solvents, water/surfactants, thermal processes, or steam.	Sediments, soils, residuals, water	Various organics and inorganics (based on technology process)
6.3 Biodegradation	Degradation of constituents of concern under aerobic or anaerobic environments.	Sediments, soils, residuals, water (< 1% suspended solids)	Organics
6.4 Chemical Treatment	Use of chemical agents to change the nature of the constituents through oxidation, reduction, neutralization, hydrolysis, dehalogenation/dechlorination, chlorinolysis, ion exchange, or photolysis.	Sediments, soils, residuals, water	Various organics and inorganics (based on technology process)
6.5 Thermal Destruction	Destruction/decomposition of wastes through the application of heat and high temperatures in an oxygen or oxygen-free atmosphere.	Sediments, soils, residuals, water	Various organics (based on technology process)
6.6 Physical Separation	Separation from media or concentration of constituents of concern through physical processes.	Sediments, soils, residuals, water	Various organics and inorganic (based on technology process)
7.0 Support Technologies			
7.1 Dewatering	Processes which increase the solids content of liquid slurries.	Sediments, soils, residuals, water	Organics, Inorganics
7.2 Debris	Washing of debris with water and detergent solutions to remove and collect constituents of concern in the wash solution for subsequent treatment, leaving washed debris for subsequent management.	Debris	Not applicable

Notes:

[1] Media which could be handled by the corresponding technology process. These media are not necessarily all inclusive of each vendor process.
[2] Constituents which could be managed by the corresponding technology process. These constituents are not necessarily all inclusive of each vendor process.

POTW - Publicly-owned Treatment Works
RCRA - Resource Conservation & Recovery Act
TSCA - Toxic Substances Control Act

TABLE 3-2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY SCREENING OF POTENTIAL REMEDIAL TECHNOLOGIES

General Response Action/ Remedial Technology	Expected Process Option	Description	Preliminary Assessment
A. No Further Action			
	-----	No further remedial activities. Ongoing natural attenuation processes would continue.	Implementable.
B. Source Control			
	Identification of External Sources	Identify and control suspected continuing sources of PCB to the Kalamazoo River.	Implementable.
	Bank Stabilization	Placement of vegetation or riprap material along the riverbank to increase stability and decrease the erosion potential of exposed sediment areas.	Implementable.
C. Institutional Controls and Monitoring			
	Access Restrictions	Constraints, such as fencing and signs, are placed on property to limit access.	Implementable on public property
	Deed Restrictions	Constraints are placed on future river use.	Implementable.
	Fish-Consumption Advisories	Advisories are issued instructing public how consumption of some fish should be limited.	Implementable; already in place.
	Pool Elevation Control	Maintenance of existing pool elevations behind dams to minimize the potential for disturbing impounded sediment beds and releasing otherwise stationary PCB for downstream transport.	Implementable; already in place.
	Monitoring	Periodic visual observations, field sampling and analysis, or other data collection would be used to monitor Site conditions.	Implementable.
D. Monitored Natural Attenuation			
	Natural Processes	The effects of ongoing physical, biological, and chemical processes that reduce PCB exposure, toxicity, and mobility would be monitored to verify decreasing concentration trends.	Readily implementable.

TABLE 3-2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY SCREENING OF POTENTIAL REMEDIAL TECHNOLOGIES
(cont'd)

General Response Action/ Remedial Technology	Expected Process Option	Description	Preliminary Assessment
E. In-Place Containment			
1. Capping	Engineered Capping/Armoring	Placement of one or more layers of materials (e.g., clean sediment, sand, gravel, cobbles, geotextile) over sediment to isolate constituents and mitigate erosion.	Implementable.
	Natural Processes	Reduce PCB bioavailability by natural processes of isolation via deposition and mixing with clean sediments.	Implementable; already occurring.
	AquaBlok™ Cap	Engineered pellets are placed through the water column and settle over the sediment. The bentonite clay coatings absorb water, coalesce, and form an impermeable layer.	No known full-scale application to PCB in sediment. Pilot scale study performed in Ottawa River.
	Asphalt Cap	Application of an asphalt or concrete layer over sediment.	Not practical for sediment.
	Particle Broadcasted Cap	Controlled application of a thin layer of capping material over PCB-containing sediment to accelerate the process of natural deposition.	Implementable.
F. Hydraulic Modification			
	Rechannelization	Construction of a "new" channel and diversion of the present river.	Implementable in some areas.
	Sedimentation Basin	Enlarging a portion of the river to reduce velocity and promote sediment deposition. The collected sediment may be removed periodically.	Implementable in some river areas; current impoundments already act in this manner.
G. Sediment Treatment			
1. Biodegradation	Natural	Naturally occurring PCB degradation by microorganisms present at the Site in an aerobic or anaerobic environment.	Implementable; some degree observed and expected to continue at the Site.
	Enhanced	Addition of nutrients (e.g., oxygen, minerals, etc.) or cultured microorganisms to the sediment to facilitate or improve the rate of natural biodegradation.	Implementable ex-situ; not practical for submerged sediment.

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ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY SCREENING OF POTENTIAL REMEDIAL TECHNOLOGIES
(cont'd)

General Response Action/ Remedial Technology	Expected Process Option	Description	Preliminary Assessment
G. Sediment Treatment (cont'd)			
2. Immobilization	Stabilization/Solidification	Chemical immobilization of materials by injecting and mixing a stabilization/solidification agent into the sediment.	Implementable ex-situ. In-situ process not yet sufficiently developed.
	Vitrification	Stabilization or destruction of constituents by melting sediment utilizing electrical currents. The melted material then solidifies to form a glasslike monolith.	Not feasible for sediment. Ex-situ operations have not been demonstrated at full scale with sediment.
3. Extraction, In-Situ	Vacuum	Create vacuum in sediment through a well; chemical constituents drawn in and extracted.	Not feasible in sediment.
	Steam	Inject steam into sediment so that chemical constituents volatilize and are removed via extraction wells.	Not feasible in sediment.
	Liquid	Solvents introduced in sediment via injection wells; extraction wells recover solvent and extracted chemical constituents.	Not feasible in sediment.
4. Extraction, Ex-Situ	Basic Extractive Sludge Treatment (BEST™)	Solvent (having inverse miscibility in water) used to remove PCB from solids.	This process has not been demonstrated at full scale with sediment.
	Low-Energy Extraction Process (LEEP)	Acetone and kerosene used as solvents to extract PCB from solids.	This process has not been developed at full scale.
	CF Systems® solvent extraction process	Critical fluids and liquefied gases such as carbon dioxide, propane, or other liquid hydrocarbons used at high pressure to separate and extract PCB from wastewater, sludge, sediment, and soil.	This process has not been demonstrated at full scale with sediment.
	Accurex Solvent Wash	A proprietary Fluorocarbon-113 and methanol solvent used to extract PCB from solids.	This process is still being developed; no full-scale operations.

 (See note on page 8.)

TABLE 3-2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY SCREENING OF POTENTIAL REMEDIAL TECHNOLOGIES
(cont'd)

General Response Action/ Remedial Technology	Expected Process Option	Description	Preliminary Assessment
G. Sediment Treatment (cont'd)			
4. Extraction, Ex-Situ (cont'd)	Methanol Extraction	Methanol used as a solvent to extract PCB from solids.	The process has not been developed at full scale.
	Terra Kleen Solvent Extraction	Solvent used to extract PCB and other organics from sediments. The solvent is separated from the materials and reused.	This process has not been demonstrated at full scale with sediment.
	Soil Washing	Sediments are separated into fractions based on particle size and density. Water with surfactants can than be used to "wash" PCB from solid fraction(s).	Limited effectiveness for PCB.
	Soil Tech Anaerobic Thermal Processor	Thermal extraction of PCB accomplished using a four-stage rotary pyrolysis processor.	Implementable.
	Low-Temperature Extraction (DAVES)	A low-temperature vapor extraction system utilizing a fluidized bed to remove PCB from sediment	Process has not been demonstrated at full scale with sediment.
	X*TRAX™	Solids heated in the presence of nitrogen, following which PCB are extracted and collected.	Process has not been demonstrated at full scale with sediment.
5. Destruction, Ex-Situ	ULTRAVIOLET (UV) DESTRUCTION		
	a. UV/Ozone/Ultrasonics	Ultrasonics used to extract PCB from solids. PCB destroyed by subsequent UV/ozone treatment.	Process still being developed.
	b. UV/Hydrogen/Ultrasonics	Ultrasonics used to extract PCB from solids. PCB destroyed by subsequent UV/hydrogen treatment.	The process reportedly is no longer being pursued by developer.
	c. Ozonation	Ozone used to decompose PCB in conjunction with UV radiation.	Destruction efficiency is reported to be too low for sediment.

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ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY SCREENING OF POTENTIAL REMEDIAL TECHNOLOGIES
(cont'd)

General Response Action/ Remedial Technology	Expected Process Option	Description	Preliminary Assessment
G. Sediment Treatment (cont'd)			
5. Destruction, Ex-Situ (cont'd)	THERMAL DESTRUCTION		
	a. Incineration	Sediment thermally treated in a fluidized bed, rotary kiln, or infrared incinerator, which would require TSCA permitting.	Implementable.
	b. Radiant Energy	UV light energy, combined with a reducing agent, used to dechlorinate PCB.	This process has not been proven to be technically feasible.
	THERMAL DESTRUCTION (CONT'D)		
	c. Pyrolysis	Use of high temperatures to decompose PCB.	Process has not been demonstrated at full scale for PCB.
	d. Plasma Arc	PCB thermally destroyed at very high temperatures.	Process has not been demonstrated at full scale for PCB.
	LOW-TEMPERATURE THERMAL DESTRUCTION		
	a. Wet Air Oxidation	A proprietary process that uses special catalysts and relatively low temperature and high pressure to decompose organic compounds.	Destruction efficiency is reported to be low for PCB.
	b. Supercritical Water Oxidation	Temperature and pressure of supercritical water dissolve materials that are oxidized into carbon dioxide, water, and salts.	Has not been demonstrated at full scale with sediment.
	DECHLORINATION		
	a. Base-Catalyzed Dechlorination (BCD)	Chlorine is stripped off PCB molecules using sodium bicarbonate in a rotary reactor.	Has not been demonstrated at full scale with sediment.
	b. Reduction (Eco Logic)	Various chemical agents (e.g., sodium borohydride, sulfur dioxide) used to destroy PCB through gas-phase reduction.	Has not been demonstrated at full scale with sediment.

TABLE 3-2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY SCREENING OF POTENTIAL REMEDIAL TECHNOLOGIES
(cont'd)

General Response Action/ Remedial Technology	Expected Process Option	Description	Preliminary Assessment
G. Sediment Treatment (cont'd)			
	c. Sodium-based Reactions (NaPEG)	PCB broken down into oxygenated organics, sodium chloride (salt), and biodegradable glycols.	Water destroys the reagent or interferes with its actions; thus, the process would require excessive drying of sediment.
H. Sediment Removal			
1. Dredging	Mechanical	Removal of bottom sediment by directly applying mechanical force to dislodge and excavate materials (e.g., clamshell).	Potentially implementable in some areas.
	Hydraulic	Removal and transportation of bottom sediment in a liquid slurry form using hydraulic dredges (e.g. cutterhead, suction, hybrid).	Potentially implementable in some areas.
	Pneumatic	Removal of bottom sediment by compressed air (e.g., PNEUMA pump).	Not feasible due to limited water depth.
	Amphibious	Removal of bottom sediment through mechanical, hydraulic, or pneumatic means via specialized amphibious dredging equipment (e.g., Aquarius-Smalley*, Amphibex).	Implementable in difficult-to-access areas with limited water depth.
2. Excavation In-the-Dry	Mechanical	Temporary structures (e.g., cofferdams) used to create "dry" areas in the river to allow use of standard excavation equipment.	Implementability questionable due to high permeability of riverbed materials.
I. Sediment Dewatering			
1. Filtration	Plate and Frame Filter Press	Sediment slurry pumped into cavities formed by a series of plates covered by a filter cloth. Liquids are forced through filter cloth and dewatered solids are collected in the filter cavities.	Implementable.
	Belt Filter Press	Sediment slurry drops onto a perforated belt where gravity drainage takes place. Thickened solids are pressed between a series of rollers to further dewater solids.	Implementable.

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ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY SCREENING OF POTENTIAL REMEDIAL TECHNOLOGIES
(cont'd)

General Response Action/ Remedial Technology	Expected Process Option	Description	Preliminary Assessment
I. Sediment Dewatering (cont'd)			
2. Centrifuge	Solid Bowl	Sediment slurry fed through a central pipe that sprays into a rotating bowl. Centrate discharges out the large end of the bowl and solids are removed from tapered end of the bowl by means of a screw conveyer.	Implementable.
3. Evaporator	Evaporator	Excess water evaporated from sediment slurry.	Implementable.
4. Hydrocyclone	Hydrocyclone	Sediment slurry fed tangentially into a funnel-shaped unit to facilitate centrifugal forces necessary to separate solids from liquids. Dewatered solids collected and overflow liquid discharged.	Implementable.
J. Sediment Disposal			
1. In-Water Disposal	Confined Disposal Facility	Sediment or residuals placed in disposal facility consisting of sheetpiling and/or earthen dikes.	Implementable.
2. Off-Site Disposal	TSCA-Regulated Landfill	Disposal of solids or residuals in existing TSCA permitted landfill.	Implementable.
	Solid Waste Landfill	Disposal of sediment in existing permitted solid waste landfill.	Implementable.
3. On-Site Disposal	On-Site Landfill	Disposal of solids in landfill(s) constructed near the Kalamazoo River.	Implementable.
K. Residuals Management			
1. Oily Residuals	Liquid Incineration	PCB from extraction processes destroyed in off-site TSCA incinerator.	Implementable.
2. Water Treatment	Activated Carbon Adsorption	PCB in aqueous phase are removed with granular-activated carbon.	Implementable.
	Distillation	PCB separated from aqueous stream by vaporization and condensation.	Likely not implementable for PCB in aqueous stream.
	Filtration	PCB filtered out through various media (i.e., sand) to effectively remove them from the liquid stream.	Implementable.
	Air or Steam Stripping	Dissolved molecules are transferred from a liquid into a flowing gas or vapor steam.	Limited implementability for PCB.

 (See note on page 8.)

TABLE 3-2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY SCREENING OF POTENTIAL REMEDIAL TECHNOLOGIES
(cont'd)

General Response Action/ Remedial Technology	Expected Process Option	Description	Preliminary Assessment
L. Fisheries Management			
	Chemical Destruction	PCB mass associated with fish tissue removed by applying chemical (e.g., Rotenone) to river, randomly killing biota.	Not feasible as PCB removal technique.
	Physical Removal	PCB mass associated with fish tissue removed by netting and trapping fish and removing from river select species (e.g., white perch).	Not feasible. Water depth in impoundments restricts area of influence of shocking equipment. Large-scale fish collection not effective.
	Electroshocking	Using electrical current, fish are stunned, select fish (e.g., white perch) retrieved, and disposed to remove PCB mass associated with fish tissue.	Not feasible. Water depth in impoundments restricts area of influence of shocking equipment. Large-scale fish collection not effective.

Note:
1 This screening analysis is based upon technical implementability without consideration of cost or particular Site issues. Shaded process options have been screened from further analysis.

TABLE 3-3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
EVALUATION OF PROCESS OPTIONS

General Response Action/Remedial Technology	Process Option	EFFECTIVENESS: Expected Ability to Meet RROs	EFFECTIVENESS: Implementation Effects	EFFECTIVENESS: How Proven and Reliable Is the Technology?	IMPLEMENTABILITY: Technical Feasibility	IMPLEMENTABILITY: Administrative Feasibility	RELATIVE COST
A. No Further Action							
	----	Would meet RROs 1 and 2 over time through naturally-occurring processes which are reducing the bioavailability and transport of PCB. Would not meet RRO 3	None.	Reliable.	Readily implementable	Readily implementable with no permits equipment required	Low.
B. Source Control							
	Identification of External Sources	RROs 2 and 3 would be met and RRO 1 would eventually be met by identifying and controlling suspected continuing sources of PCB to the Kalamazoo River.	Effects of implementation would be determined after identifying external PCB sources	Cannot definitively be ascertained at this time. Industrial controls are expected to be reliable.	Cannot definitively be ascertained at this time. Industrial controls are expected to be technically feasible	Cannot definitively be ascertained at this time. Industrial controls are expected to be administratively feasible	Low to moderate
	Bank Stabilization	Would reduce erosion potential of riverbank soils. Would meet RROs by reducing PCB transport to Lake Michigan and controlling PCB sources to the Kalamazoo River.	Possible short-term impairment to shoreline ecosystems in stabilized bank areas only. Effects could be reduced by use of engineering controls and post-implementation restoration efforts.	Reliable	Implementable.	Access negotiations with potentially affected landowner(s) would be necessary. Equipment, materials, and personnel are commercially available.	Moderate.
C. Institutional Controls and Monitoring							
	Access Restrictions	Reduces potential for consumption of fish containing PCB. RROs 1 and 2 eventually would be met through naturally-occurring processes. RRO 3 would not be met.	None.	Reliable.	Readily implementable.	Some access restrictions already in place. Further restrictions readily implementable on PRP properties. Restrictions for other properties and public access areas may present implementation difficulties	Low to moderate
	Deed Restrictions	Informs property owners of potential risks associated with property. RROs 1 and 2 eventually would be met through naturally-occurring processes. RRO 3 would not be met.	None.	Reliable.	Readily implementable.	Implementable. Negotiations with potentially affected landowner(s) would be necessary	Low to moderate

(See note on page 13)

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
EVALUATION OF PROCESS OPTIONS
(cont'd)

General Response Action/Remedial Technology	Process Option	EFFECTIVENESS			IMPLEMENTABILITY		RELATIVE COST
		Expected Ability to Meet RROs	Implementation Effects	How Proven and Reliable Is the Technology?	Technical Feasibility	Administrative Feasibility	
C. Institutional Controls (cont'd)							
	Consumption Advisories	Reduces potential for ingestion of fish containing PCB. RROs 1 and 2 eventually would be met through naturally-occurring processes. RRO 3 would not be met.	None.	Reliable.	Readily implementable, already in place	Readily implementable, already in place	Low.
	Pool Elevation Control	Requires maintenance of current pool elevations in the impoundments. RROs 1 and 2 eventually would be met through naturally-occurring processes. RRO 3 would not be met.	Minimal; dams currently in place.	Reliable. Assumes that dams and impoundments are operated and maintained by their owners in compliance with applicable laws and regulations prohibiting the exacerbation of existing environmental contamination.	Readily implementable. Dams are currently in place and would require periodic inspection and maintenance.	Readily implementable, laws requiring controls are already in place.	Moderate.
	Monitoring	Periodic visual observations and/or field sampling to monitor Site conditions. RROs 1 and 2 eventually would be met through naturally occurring processes. RRO 3 would not be met.	Minimal; limited activity.	Reliable means to track Site conditions.	Readily implementable.	Readily implementable, with specialized services required and available, permits not required under CERCLA, although substantive requirements would need to be met. State collection permit may be appropriate.	Low to moderate.
D. Monitored Natural Attenuation							
	Natural Processes	Meets RRO 1 by reducing PCB bioavailability over time due to natural attenuation processes, including isolation primarily through natural deposition/mixing. Not likely to achieve immediate reduction of PCB in fish or reduce ingestion of fish containing PCB, but reduction in PCB bioavailability would result in eventual achievement of RROs	None	Reliable, included in remedial decisions for 11 Great Lakes sites. Remedial investigation results indicate continuing decline in PCB concentrations in fish	Readily implementable.	Natural process, no permits, specialized equipment, or personnel are necessary	Negligible

(See note on page 13)

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
EVALUATION OF PROCESS OPTIONS
(cont'd)

General Response Action/Remedial Technology	Process Option	EFFECTIVENESS			IMPLEMENTABILITY		RELATIVE COST
		Expected Ability to Meet RROs	Implementation Effects	How Proven and Reliable Is the Technology?	Technical Feasibility	Administrative Feasibility	
E. In-Place Containment							
1. Capping	Engineered Capping/ Armoring	Meets RRO 1 by reducing PCB bioavailability due to isolation. Not likely to achieve prompt reduction of PCB in fish due to long implementation time. Would result in eventual achievement of RROs 2 and 3	Possible increased risk and disruption to natural processes during remediation, including destruction of benthic community in capped area. Effects could be reduced by use of engineering controls to mitigate release of sediment resuspended during construction of cap.	USACE has demonstrated capping of PCB-containing sediments at a number of sites nationwide (none at the same scale as the Site). Several full-scale capping projects have been successfully undertaken in harbors, lakes and the sea. Capping is expected to be reliable for sediments	Implementable. Cap/armor may be more challenging to place in shallow waters of the former impoundments and free-flowing river sections. Construction of roadways would be required for access to river	Access negotiations with potentially affected property owners would be necessary. Equipment, materials, and personnel are commercially available.	Moderate to high
	Particle Broadcasted Cap	Meets RRO 1 by reducing PCB bioavailability due to isolation. Not likely to achieve prompt reduction of PCB in fish. Would result in eventual achievement of RROs 2 and 3.	Possible increased risk and disruption to natural processes during remediation, including destruction of benthic community in capped area. Effects could be reduced by use of engineering controls to mitigate release of sediment resuspended during construction of cap.	Previously demonstrated at the Pier 64 Capping Project (Seattle, Washington), and the Eagle Harbor Superfund Site (Seattle, Washington), and is proposed for Ward Cove (Ketchikan, Alaska). Technology also has been demonstrated internationally in Japan and Canada (Hamilton Harbour).	Implementable. Most appropriate for use in depositional areas (e.g., impoundments). Construction of roadways would be required for access to river.	Access negotiations with potentially affected property owners would be necessary. Equipment, materials, and personnel are commercially available.	Moderate.
	AquaBlok™ Cap	Meets RRO 1 by reducing PCB bioavailability due to isolation. Not likely to achieve prompt reduction of PCB in fish due to long implementation time. Would result in eventual achievement of RROs 2 and 3	Possible increased risk and disruption to natural processes during remediation, including destruction of benthic community in capped area. Effects could be reduced by use of engineering controls to mitigate release of sediment resuspended during construction of cap	Has not been demonstrated to be reliable over the long term when used to cap PCB sediments. Concerns raised about viability of bentonite as a substrate for benthos.	Implementable. Cap/armor may be more challenging to place in shallow waters of the former impoundments and free-flowing river sections. Construction of roadways would be required for access to river	Access negotiations with potentially affected landowner(s) would be necessary. Equipment, materials, and personnel are commercially available	Moderate to high

(See note on page 13)

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
EVALUATION OF PROCESS OPTIONS
(cont'd)

General Response Action/Remedial Technology	Process Option	EFFECTIVENESS: Expected Ability to Meet RROs	EFFECTIVENESS: Implementation Effects	EFFECTIVENESS: How Proven and Reliable Is the Technology?	IMPLEMENTABILITY: Technical Feasibility	IMPLEMENTABILITY: Administrative Feasibility	RELATIVE COST
F. Hydraulic Modification							
	Rechannelization	Reduces water column contact with PCB-containing sediment, thereby decreasing bioavailability to fish. Not likely to achieve prompt reduction of PCB in fish or reduce ingestion of fish containing PCB. Would result in eventual achievement of all RROs.	Would substantially disturb ecological habitat and surrounding area. Potential risks to humans could be minimized by use of engineering controls. Unforeseen effects (e.g., flooding) possible.	Has been selected as part of remedial actions in Wisconsin (Moss American Site). "Old" channel would need to be addressed (e.g., filled in).	Only applicable in limited portions of the river where physical configuration and limited development exist (e.g., avoid flooding potential).	Access negotiations with potentially affected landowners would be necessary due to property acquisition for relocation. Given that the river flows through several cities/towns, public opposition is likely. Equipment, materials, and personnel are commercially available.	High
	Sedimentation Basin	Reduces transport and facilitates capture of PCB-containing sediment. Also allows for a more rapid deposition of "clean" surficial sediments over time. Processes already occurring in current impoundments. Not likely to achieve prompt reduction of PCB in fish. Creation of additional sedimentation basins would significantly disturb and/or modify ecological habitat by creating new silty deposits and significantly enlarging in-river depositional areas.	Would significantly alter river hydraulics. Potential effects could be addressed by use of engineering controls. Unforeseen effects (e.g., flooding) are possible. Possibly could increase chance of upstream flooding during extreme events.	The basic design criteria are well established; however, generally applied on a smaller scale than that required for the Kalamazoo River (e.g., storm water retention basin). A new sedimentation basin(s) would remove only a fraction of the sediment being transported downstream.	Not likely feasible in developed areas or in areas already impounded by existing dam structures. Equipment, materials, and personnel are commercially available.	Access negotiations with potentially affected landowner(s) would be necessary due to property acquisition and potential relocation requirements. While possible to construct, would result in a new impoundment in a 52-mile stretch of the Kalamazoo River, which already contains several impoundments. Equipment, materials, and personnel are commercially available.	High to very high.

(See note on page 13)

TABLE 3-3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
EVALUATION OF PROCESS OPTIONS
(cont'd)

General Response Action/Remedial Technology	Process Option	EFFECTIVENESS			IMPLEMENTABILITY		RELATIVE COST
		Expected Ability to Meet RROs	Implementation Effects	How Proven and Reliable Is the Technology?	Technical Feasibility	Administrative Feasibility	
G. Sediment Treatment							
1. Biodegradation	Natural, In-situ	Biodegradation breaks down PCB in sediment, eventually resulting in reductions in toxicity. Not likely to achieve prompt reduction of PCB in fish or reduce ingestion of fish containing PCB, but together with other natural processes would result in eventual reduction in PCB bioavailability and achievement of RROs.	None.	Biodegradation of PCB is a slow process. However, research evidence at many sites has shown that biodegradation can and does exist. Can be effective with other natural processes following source control.	Readily implementable.	Natural process, no permits, specialized equipment, or personnel required	Negligible
2. Immobilization	Ex-Situ Stabilization/ Solidification	Does not in and of itself meet RROs, but may be considered in conjunction with other technologies (e.g., removal, dewatering, disposal, residuals management) to form potential remedial actions that can meet RROs.	Potential effects if any could be reduced through use of engineering controls. Reduces mobility of PCB but increases disposal volume.	Process option has been shown to be effective ex-situ and demonstrated full scale at several Superfund sites. Utilized to reduce free moisture for disposal purposes.	Implementable.	If performed on-Site, access negotiations with potentially affected landowners would be necessary. Equipment, materials, and technical support are available.	Moderate to high.
3. Extraction, Ex-Situ	SoilTech Anaerobic Thermal Processor	Does not in and by itself meet RROs, but may be considered in conjunction with other technologies (e.g., removal, dewatering, residuals management) to form potential remedial actions that eventually may meet RROs. However, if located off-Site, transportation and handling of concentrated extracted PCB introduces potential risks of accidental release of PCB on public highways.	Potential effects could be mitigated through use of engineering controls. Extraction residuals may have limited disposal options. Emissions data collected during full-scale operations have indicated that dioxin emissions may be an issue. Risk of release potential also exists with transportation of materials.	Used full-scale at Waukegan Harbor Superfund Site.	Feasibility questionable; moisture content of feed materials limited to 20%. Would require treatability study to determine whether other Site-specific factors make it feasible.	Equipment, materials, and technical support available from manufacturer. If performed on-Site, access negotiations with potentially affected landowners would be necessary. Permits required for off-site incineration. Space limitations exist.	Very high.

(See note on page 13)

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
EVALUATION OF PROCESS OPTIONS
(cont'd)

General Response Action/Remedial Technology	Process Option	EFFECTIVENESS			IMPLEMENTABILITY		RELATIVE COST
		Expected Ability to Meet RROs	Implementation Effects	How Proven and Reliable Is the Technology?	Technical Feasibility	Administrative Feasibility	
G. Sediment Treatment (cont'd)							
4. Destruction, Ex-Situ	Incineration	Does not in and by itself meet RROs, but may be considered in conjunction with other technologies (e.g., removal, dewatering, disposal, residuals management) to form potential remedial actions that eventually may meet RROs. However, if located off-Site, transportation and handling of sediment may introduce potential risks of accidental release of PCB on public highways.	Emissions of products of incomplete combustion and unburned PCB during incineration are of concern. Risk of release potential also exists with transportation of materials.	Incineration of PCB-containing materials in incinerators has been demonstrated at several sites in the U.S.	Incineration is expected to be feasible.	Full-scale units and technical assistance/support currently are available for incineration. If performed on-Site, access negotiations with potentially affected landowners would be necessary. Public resistance to incineration likely to be high. Permits required for off-Site incineration.	Very high.

(See note on page 13)

TABLE 3-3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
EVALUATION OF PROCESS OPTIONS
(cont'd)

General Response Action/Remedial Technology	Process Option	EFFECTIVENESS			IMPLEMENTABILITY		RELATIVE COST
		Expected Ability to Meet RROs	Implementation Effects	How Proven and Reliable Is the Technology?	Technical Feasibility	Administrative Feasibility	
II. Sediment Removal							
1. Dredging	Mechanical	Does not in and by itself meet RROs, but may be considered in conjunction with other technologies (e.g., disposal, dewatering, residuals management) to form potential remedial actions that eventually may meet RROs. Removal of PCB-containing sediment and subsequent reduction in surface PCB concentration tend to reduce bioavailability of PCB to fish in the long term. However, technological limitations of dredging (i.e., resuspension of sediment, lack of ability to remove all sediment) could result in higher surficial PCB concentrations. Not likely to achieve prompt reduction of PCB in fish or reduce ingestion of fish containing PCB	Effects might be mitigated to some extent by use of engineering controls, and limiting worker contact with sediments. Would destroy ecological habitat, and may result in increased residual PCB concentrations at locations where higher PCB concentrations exist at depth. During periods of insufficient water levels or high flow/storm events, operations would need to be suspended. Disturbance of ecological habitat will be significant in areas where removal occurs.	Experience at this and other PCB sites indicates that residual PCB concentrations are difficult to predict, and very low residual levels of PCB have not been consistently achieved.	Implementable only if adequate access is available (i.e., sufficiently deep water for a barge, or usable riverbank in proximity) - conditions which do not exist in all areas of the Kalamazoo River. Removal rates anticipated to be greatly reduced from typical navigation dredging project, resulting in long implementation times.	Access negotiations with affected landowner(s) would be necessary. Would be disruptive of most river impoundment activities. Equipment, materials, and technical support available.	Moderate to high.

(See note on page 13)

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
EVALUATION OF PROCESS OPTIONS
(cont'd)

General Response Action/Remedial Technology	Process Option	EFFECTIVENESS			IMPLEMENTABILITY		RELATIVE COST
		Expected Ability to Meet RROs	Implementation Effects	How Proven and Reliable Is the Technology?	Technical Feasibility	Administrative Feasibility	
II. Sediment Removal (cont'd)							
1 Dredging (cont'd)	Hydraulic	Does not in and by itself meet RROs, but may be considered in conjunction with other technologies (e.g., disposal, dewatering, residuals management) to form potential remedial actions that eventually may meet RROs. Removal of PCB-containing sediment and subsequent reduction in surface PCB concentration tend to reduce bioavailability of PCB to fish in the long term. However, technological limitations of dredging (i.e., resuspension of sediment, lack of ability to remove all sediment) could result in higher surficial PCB concentrations. Not likely to achieve prompt reduction of PCB in fish or reduce ingestion of fish containing PCB.	Effects might be mitigated to some extent by use of engineering controls, and limiting worker contact with sediments. Would destroy ecological habitat, and may result in increased residual PCB concentrations at locations where higher PCB concentrations exist at depth. During periods of insufficient water levels or high flow/storm events, operations would need to be suspended. Generates extremely large volumes of water, requiring temporary storage and subsequent treatment. Disturbance of ecological habitat will be significant in areas where removal occurs.	Experience at other PCB sites indicates that residual PCB concentrations are difficult to predict, and very low residual levels of PCB are not consistently achievable	Implementable in some portions of the Site only if sufficient access is available (e.g., current impoundments). Shallow waters, presence of boulders/debris make this less feasible in other areas. Limited access areas may require increased dredge pipeline length. Removal rates anticipated to be greatly reduced from typical navigation dredging project, resulting in long implementation times	Access negotiations with affected landowner(s) would be necessary. Would be disruptive of most river/impoundment activities. Limited space for sediment processing and extensive water treatment may present substantial difficulties. Equipment, materials, and technical personnel available	Moderate to high

(See note on page 13)

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
EVALUATION OF PROCESS OPTIONS
(cont'd)

General Response Action/Remedial Technology	Process Option	EFFECTIVENESS			IMPLEMENTABILITY		RELATIVE COST
		Expected Ability to Meet RROs	Implementation Effects	How Proven and Reliable Is the Technology?	Technical Feasibility	Administrative Feasibility	
H. Sediment Removal (cont'd)							
1 Dredging (cont'd)	Amphibious	Does not in and by itself meet RROs, but may be considered in conjunction with other technologies (e.g., disposal, dewatering, residuals management) to form potential remedial actions that eventually may meet RROs. Removal of PCB-containing sediment and subsequent reduction in surface PCB concentration tend to reduce bioavailability of PCB to fish in the long term. However, technological limitations of dredging (i.e., resuspension of sediment, lack of ability to remove all sediment) could result in higher surficial PCB concentrations. Not likely to achieve prompt reduction of PCB in fish or reduce ingestion of fish containing PCB	Effects could be mitigated by use of engineering controls and limiting worker contact with sediments. Would destroy ecological habitat, and may result in increased residual PCB concentrations at locations where higher PCB concentrations exist at depth. Affected by adverse (i.e., rising water) weather conditions. Water levels would dictate whether track-mounted or pontoon-type equipment is used. Disturbance of ecological habitat would be significant in areas where removal occurs.	Relatively new technology with limited application. Could be reliable in difficult-to-access areas. As noted at this and other PCB sites involving sediment removal, residual PCB concentrations are difficult to predict, and very low residual levels of PCB are not consistently achievable.	Implementable only if adequate access is available and weather conditions are not adverse (i.e., appropriate water depth). Removal rates anticipated to be greatly reduced from typical navigation dredging project, resulting in long implementation times.	Access negotiations with affected landowner(s) would be necessary. Would be disruptive of most river impoundment activities. Equipment, materials, and technical support available.	High

(See note on page 13)

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
EVALUATION OF PROCESS OPTIONS
(cont'd)

General Response Action/Remedial Technology	Process Option	EFFECTIVENESS			IMPLEMENTABILITY		RELATIVE COST
		Expected Ability to Meet RROs	Implementation Effects	How Proven and Reliable Is the Technology?	Technical Feasibility	Administrative Feasibility	
II. Sediment Removal (cont'd)							
2. Excavation In-the-Dry	Mechanical	Does not in and by itself meet RROs, but may be considered in conjunction with other technologies (e.g., disposal, dewatering, residuals management) to form potential remedial actions that eventually may meet RROs. Removal of PCB-containing sediment and subsequent reduction in surface concentration tend to reduce bioavailability of PCB to fish in the long term. However, technological limitations of excavation (e.g., lack of ability to remove all sediment) could result in higher surficial PCB concentrations left behind. Not likely to achieve prompt reduction of PCB in fish or reduce ingestion of fish containing PCB.	Effects might be mitigated to some extent by use of engineering controls and limiting worker contact with sediments. Increased potential for localized flooding exists. Destruction of ecological habitat will occur in areas where removal occurs.	Typically applied on a smaller scale than would be necessary at the Site. Experience at other PCB sites indicates that residual PCB concentrations are difficult to predict, and very low residual levels of PCB are not consistently achievable.	Implementability concerns with potential water overtopping, ground water infiltration and unknown riverbed characteristics. Effectiveness of obtaining "dry" conditions questionable due to unknown riverbed conditions (e.g., depth to bedrock, degree of fracture, river water levels). Installation and removal of containment structure greatly reduces overall removal rates, resulting in implementation times of decades.	Access negotiations with potentially affected landowner(s) would be necessary. Would be disruptive of most river/impoundment activities. Equipment, materials, and technical support available.	High.

(See note on page 13)

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
EVALUATION OF PROCESS OPTIONS
(cont'd)

General Response Action/Remedial Technology	Process Option	EFFECTIVENESS			IMPLEMENTABILITY		RELATIVE COST
		Expected Ability to Meet RROs	Implementation Effects	How Proven and Reliable Is the Technology?	Technical Feasibility	Administrative Feasibility	
I. Sediment Dewatering							
1. Filtration	Plate and Frame Filter Press	Does not meet RROs on its own, but may be necessary for removed sediments that are high in water content prior to disposal	Minimal, assuming waste streams are properly managed. High worker exposure to PCB-containing sediment and water.	Reliable. Effectiveness limited by physical characteristics of sediment.	Implementable.	Space limitations exist. Equipment, materials, and technical support readily available.	Moderate.
	Belt Filter Press	Does not meet RROs on its own, but may be necessary for removed sediments that are high in water content prior to disposal	Minimal, assuming waste streams are properly managed. High worker exposure to PCB-containing sediment and water.	Reliable. Effectiveness limited by physical characteristics of sediment.	Implementable; continuous operation.	Space limitations exist. Equipment, materials, and technical support readily available.	Moderate.
2. Centrifuge	Solid Bowl	Does not meet RROs on its own, but may be necessary for removed sediments that are high in water content prior to disposal.	Minimal, assuming waste streams are properly managed. High worker exposure to PCB-containing sediment and water.	Historically, process has required frequent maintenance and has often experienced operational difficulties. Effectiveness limited by physical characteristics of sediment.	Implementable, continuous operation.	Space limitations exist. Equipment, materials, and technical support readily available.	Moderate
3. Evaporator	Evaporator	Does not meet RROs on its own, but may be necessary for removed sediments that are high in water content prior to disposal.	Minimal, assuming waste streams are properly managed. Potential for worker exposure to PCB-containing sediment.	Reliable. Effectiveness limited by physical characteristics of sediment.	Implementable. May produce drier cake than required, not usually employed for sediments	Space limitations exist. Equipment, materials, and technical support readily available.	High
4. Hydrocyclone	Hydrocyclone	Does not meet RROs on its own, but may be necessary for removed sediments that are high in water content prior to disposal	Minimal, assuming waste streams are properly managed. High worker exposure to PCB-containing sediment and water.	Reliable. Effectiveness limited by physical characteristics of sediment. Used at Manistique Harbor, Michigan.	Implementable, continuous operation. Most effective on feed with high coarse particle content (i.e., sand) and solids content 5 to 25%.	Space limitations exist. Equipment, materials, and technical support readily available.	Low to moderate

(See note on page 13)

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
EVALUATION OF PROCESS OPTIONS
(cont'd)

General Response Action/Remedial Technology	Process Option	EFFECTIVENESS			IMPLEMENTABILITY		RELATIVE COST
		Expected Ability to Meet RROs	Implementation Effects	How Proven and Reliable Is the Technology?	Technical Feasibility	Administrative Feasibility	
J. Sediment Disposal							
1. In-Water Disposal	Confined Disposal Facility (CDF)	Does not meet RROs on its own, but can be used in conjunction with other technologies (e.g., removal, dewatering, residuals management) to form remedial actions that eventually may meet RROs.	Effects could be reduced through use of engineering controls.	Technology used at New Bedford Harbor, Massachusetts, Saginaw Bay, Michigan, Waukegan Harbor, Illinois, and other sites in the Great Lakes.	Most cost-effective with large sediment volumes. Due to large volume of sediments and length of effective river, not likely to locate a single "in water" area with sufficient capacity.	Equipment and technical support readily available. Likely agency/public opposition.	Moderate
2. Off-Site Disposal	TSCA-Regulated Landfill	Does not meet RROs on its own, but can be used in conjunction with other technologies (e.g., removal, dewatering, residuals management) to form remedial actions that eventually may meet RROs.	Effects could be reduced through use of engineering controls. Risks of exposure and transportation accidents increase with transport of sediment.	Widely used.	Expected to be feasible. Depends on landfill location, availability, and capacity.	Equipment and technical support readily available	Moderate to high
	Solid Waste Landfill	Does not meet RROs on its own, but can be used in conjunction with other technologies (e.g., removal, dewatering, residuals management) to form remedial actions that eventually may meet RROs.	Effects could be reduced through use of engineering controls. Risks of exposure and transportation accidents increase with transport of materials.	Widely used	Expected to be feasible. Depends on landfill location, availability, and capacity	Equipment and technical support readily available.	Low to moderate.
3. On-Site Disposal	On-Site Landfill	Does not meet RROs on its own, but can be used in conjunction with other technologies (e.g., removal, dewatering, residuals management) to form remedial actions that eventually may meet RROs.	Effects could be reduced through use of engineering controls.	Widely used.	Expected to be feasible. Potential difficulties exist with acquiring appropriate permits.	Ability to locate and purchase sufficient land in vicinity critical. Equipment and technical support readily available. Public opposition also anticipated	Moderate to high

(See note on page 13)

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
EVALUATION OF PROCESS OPTIONS
(cont'd)

General Response Action/Remedial Technology	Process Option	EFFECTIVENESS			IMPLEMENTABILITY		RELATIVE COST
		Expected Ability to Meet RROs	Implementation Effects	How Proven and Reliable Is the Technology?	Technical Feasibility	Administrative Feasibility	
K. Residuals Management							
1. Oily Residuals	Liquid Incineration	Does not meet RROs on its own, but can be used in conjunction with other technologies (e.g., removal, dewatering, disposal) to form remedial actions that eventually may meet RROs.	Increased risks due to emissions of products of incomplete combustion and unburned PCB. Risks of exposure increased with transport and handling of materials.	Technology shown to effectively destroy PCB in liquid stream.	Expected to be feasible. May be only option for handling PCB oils from PCB extraction processes, if selected.	Limited full-scale permitted facilities in operation. Public opposition likely	Very high.
2. Water Treatment (e.g., water from dewatered sediment)	Activated Carbon Adsorption	Does not meet RROs on its own, but can be used in conjunction with other technologies (e.g., removal, dewatering, disposal) to form remedial actions that eventually may meet RROs. Could be applied to aqueous-based residuals from PCB treatment technologies or water generated during dewatering.	Effects could be mitigated through use of engineering controls. Spent carbon would require proper disposal.	Activated carbon commonly used for water treatment. Considered Best Available Technology (BAT) for PCB in water by USEPA.	Implementable.	Equipment, materials, and technical support readily available	Low to moderate
	Filtration	Does not meet RROs on its own, but can be used in conjunction with other technologies (e.g., removal, dewatering, disposal) to form remedial actions that eventually may meet RROs. Could be applied to aqueous-based residuals from PCB treatment technologies or water generated during dewatering	Effects could be mitigated through use of engineering controls.	Technology widely used as an effective PCB water treatment.	Implementable.	Equipment, materials, and technical support readily available.	Low to moderate

Note:

Shade denotes technologies/process options not retained for assembly into remedial alternatives

TABLE 4-1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 1 - NO FURTHER ACTION

SUMMARY OF CAPITAL COSTS

Item No.	Description	Quantity	Unit	Unit Cost	Item Cost
1	None			$0	$0

SUMMARY OF O&M COSTS

Item No.	Description	Quantity	Unit	Unit Cost	Item Cost
1	None			$0	$0

TABLE 4-2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 2 - INSTITUTIONAL CONTROLS AND MONITORING

SUMMARY OF CAPITAL COSTS

Item No.	Description	Quantity	Unit	Unit Cost (rounded)	Item Cost (rounded)
1	None			$0	$0

SUMMARY OF O&M COSTS

Item No.	Description	Quantity	Unit	Unit Cost (rounded)	Item Cost (rounded)
1	**Biota sampling and analysis** Trend monitoring for PCB and percent lipids in biota	1	lump sum	$75,000	$75,000
	SUBTOTAL				$75,000
	15% Engineering/Coordination				$11,000
	20% Contingency				$15,000
				TOTAL (1 YEAR):	$101,000
				TOTAL (8 EVENTS):	$808,000
				PRESENT VALUE:	$462,000
2	**Surface water and sediment sampling and analysis** Monitoring surface water samples for PCB, and sediment samples for PCB, ^{137}Cs, particle size, bulk density, and specific gravity	1	lump sum	$47,000	$47,000
	SUBTOTAL				$47,000
	15% Engineering/Coordination				$7,000
	20% Contingency				$9,000
				TOTAL (1 YEAR):	$63,000
				TOTAL (6 EVENTS):	$378,000
				PRESENT VALUE:	$191,000
				TOTAL COST:	$1,186,000
				TOTAL PRESENT WORTH:	$653,000

(See notes on page 2.)

TABLE 4-2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 2 - INSTITUTIONAL CONTROLS AND MONITORING

NOTES/ASSUMPTIONS

General

- All costs include material and labor, unless otherwise noted.
- Costs do not include legal fees, permitting, obtaining access, negotiations, or agency oversight.
- Unit costs are in 2000 dollars.
- Costs based on current site information and project understanding. This may change following collection of additional data and/or receipt of Agency input and actual project design.
- Present worth is estimated based on a 7 percent (%) beginning-of-year discount rate (adjusted for inflation) in accordance with USEPA policy directive entitled "Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis," OSWER Directive No. 9355.3-20 (USEPA, 1993). It is assumed that Year 0 is 2000.
- Engineering fees are assumed to be 15% of the total cost before fees and contingency allowance.
- A 20% contingency allowance is included to provide for unforeseen circumstances or variability in estimated areas, volumes, labor, and material costs.

Component-Specific

- Biota monitoring includes skin-on fillet and whole body composite samples. Biota monitoring assumed to be performed in years 0, 2, 4, 6, 9, 14, 24, and 29 following remedy implementation.
- Surface water and sediment will be collected from three discrete locations in the Kalamazoo River. Monitoring will be performed in years 0, 4, 9, 14, 24, and 29 following remedy implementation. Surface water will be analyzed for PCB. Sediment will be analyzed for PCB and ^{137}Cs, as well as particle size, bulk density, and specific gravity.

TABLE 4-3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 3 - BANK STABILIZATION AT THE FORMER IMPOUNDMENTS,
MONITORED NATURAL ATTENUATION, AND INSTITUTIONAL CONTROLS

SUMMARY OF CAPITAL COSTS

Item No.	Description	Quantity	Unit	Unit Cost (rounded)	Item Cost (rounded)
Bank Stabilization					
A	**Plainwell Impoundment (Construction in Year 2003)**				
	1 Mobilization/demobilization	1	lump sum	$166,000	$166,000
	2 General conditions	1	lump sum	$83,000	$83,000
	3 Clearing	20,000	linear foot	$21	$420,000
	4 Access road construction/restoration	47,000	square yard	$27	$1,269,000
	5 River bank restoration				
	River bank stabilization	56,000	square yard	$40	$2,240,000
	River bank backfill	15,000	cubic yard	$20	$300,000
	6 Habitat enhancement				
	Bioengieered bank soil backfill	7,000	cubic yard	$20	$140,000
	Bioengineered banks	10,000	square yard	$40	$400,000
	Vegetation/restoration	28,000	square yard	$15	$420,000
	7 Erosion control (silt fence and curtain)	26,000	linear foot	$5	$130,000
	8 Barge/work platform	4	month	$53,500	$214,000
	SUBTOTAL				$5,782,000
	Engineering fees and project management (13%)				$752,000
	Construction management (6%)				$347,000
	Contingency (20%)				$1,156,000
				TOTAL (YEAR 3):	$8,037,000
				PRESENT VALUE:	$6,561,000
B	**Otsego Impoundment (Construction in Year 2004)**				
	1 Mobilization/demobilization	1	lump sum	$189,000	$189,000
	2 General conditions	1	lump sum	$95,000	$95,000
	3 Clearing	22,000	linear foot	$21	$462,000
	4 Access road construction/restoration	52,000	square yard	$27	$1,404,000
	5 River bank restoration				
	River bank stabilization	64,000	square yard	$40	$2,560,000
	River bank backfill	20,000	cubic yard	$20	$400,000
	6 Habitat enhancement				
	Bioengieered bank soil backfill	8,000	cubic yard	$20	$160,000
	Bioengineered banks	12,000	square yard	$40	$480,000
	Vegetation/restoration	32,000	square yard	$15	$480,000
	7 Erosion control (silt fence and curtain)	29,000	linear foot	$5	$145,000
	8 Barge/work platform	4	month	$53,500	$214,000
	SUBTOTAL				$6,589,000
	Engineering fees and project management (13%)				$857,000
	Construction management (6%)				$395,000
	Contingency (20%)				$1,318,000
				TOTAL (YEAR 4):	$9,159,000
				PRESENT VALUE:	$6,987,000

(See notes on page 4.)

TABLE 4-3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 3 - BANK STABILIZATION AT THE FORMER IMPOUNDMENTS,
MONITORED NATURAL ATTENUATION, AND INSTITUTIONAL CONTROLS

SUMMARY OF CAPITAL COSTS (CONT'D)

Item No.	Description	Quantity	Unit	Unit Cost (rounded)	Item Cost (rounded)
Bank Stabilization (cont'd)					
C	**Trowbridge Impoundment (Construction in Years 2005 and 2006)**				
	1 Mobilization/demobilization	1	lump sum	$548,000	$548,000
	2 General conditions	1	lump sum	$274,000	$274,000
	3 Clearing	63,000	linear foot	$21	$1,323,000
	4 Access road construction/restoration	148,000	square yard	$27	$3,996,000
	5 River bank restoration				
	River bank stabilization	190,000	square yard	$40	$7,600,000
	River bank backfill	50,000	cubic yard	$20	$1,000,000
	6 Habitat enhancement				
	Bioengieered bank soil backfill	23,000	cubic yard	$20	$460,000
	Bioengineered banks	35,000	square yard	$40	$1,400,000
	Vegetation/restoration	95,000	square yard	$15	$1,425,000
	7 Erosion control (silt fence and curtain)	83,000	linear foot	$5	$415,000
	8 Barge/work platform	12	month	$53,500	$642,000
	SUBTOTAL				$19,083,000
	Engineering fees and project management (11%)				$2,099,000
	Construction management (6%)				$1,145,000
	Contingency (20%)				$3,817,000
				TOTAL (YEARS 5 & 6):	$26,144,000
				PRESENT VALUE:	$18,031,000
				TOTAL CAPITAL COST:	$43,340,000
				PRESENT VALUE:	$31,579,000

(See notes on page 4.)

TABLE 4-3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 3 - BANK STABILIZATION AT THE FORMER IMPOUNDMENTS, MONITORED NATURAL ATTENUATION, AND INSTITUTIONAL CONTROLS

SUMMARY OF O&M COSTS

Item No.	Description	Quantity	Unit	Unit Cost (rounded)	Item Cost (rounded)
D	**Perform post-remedy visual observation of the stabilized banks**				
	1 Administrative and coordination	1	lump sum	$3,200	$3,200
	2 Mobilization/Demobilization	1	lump sum	$6,500	$6,500
	3 Visual observations of stabilized banks (above water)	10	day	$2,200	$22,000
	4 Visual observations of stabilized banks (below water)	20	day	$3,800	$76,000
	5 Reporting	1	lump sum	$10,000	$10,000
	SUBTOTAL				$118,000
	Engineering fees (15%)				$18,000
	Contingency (20%)				$24,000
				TOTAL (1 EVENT):	$160,000
				TOTAL (7 EVENTS, YEARS 7 THROUGH 37):	$1,120,000
				PRESENT VALUE:	$315,000
E	**Care and maintenance of restored banks** Repairing local erosions, wash outs, vegetation touch ups, etc.	1	lump sum	$1,572,700	$1,572,700
	SUBTOTAL				$1,572,700
	Engineering fees (15%)				$236,000
	Contingency (20%)				$315,000
				TOTAL (1 EVENT):	$2,123,700
				TOTAL (7 EVENTS, YEARS 7 THROUGH 37):	$14,866,000
				PRESENT VALUE:	$4,176,000
F	**Institutional controls and monitoring**				
	1 Water column sampling	8	one event/5-years	$331,000	2,648,000
	2 Sediment sampling	8	one event/5-years	$249,000	1,992,000
	3 Biota sampling and monitoring - advisory	8	one event/5-years	$398,000	3,184,000
	4 Biota sampling and monitoring - trend	12	one event/3-years	$143,000	1,716,000
	5 KALSIM model updates	8	one event/5-years	$540,000	$4,320,000
				TOTAL (YEARS 3 THROUGH 37):	$13,860,000
				PRESENT VALUE:	$4,609,000
				TOTAL O&M COSTS:	$29,846,000
				PRESENT VALUE:	$9,100,000
				GRAND TOTAL COST:	$73,186,000
				GRAND TOTAL PRESENT WORTH COST:	$40,679,000

(See notes on page 4.)

TABLE 4-3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 3 - BANK STABILIZATION AT THE FORMER IMPOUNDMENTS, MONITORED NATURAL ATTENUATION, AND INSTITUTIONAL CONTROLS

General

- All costs include material and labor, unless otherwise noted.
- Costs do not include legal fees, permitting, obtaining access, negotiations, or agency oversight.
- Unit costs are in 2000 dollars and are estimated from standard estimating guides (e.g. Means Site Work and Landscape Cost Data, vendors, professional judgement and experience from other similar projects).
- Costs based on current site information and project understanding. This may change following collection of additional data and/or receipt of Agency input and actual project design.
- Cost estimates are generally developed based on the USEPA guidance document "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study," EPA 540-R-00-002 (OSWER 9355.0-75) dated July 2000.
- Present worth is estimated based on a 7 percent (%) beginning-of-year discount rate (adjusted for inflation) in accordance with USEPA policy directive entitled "Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis", OSWER Directive No. 9355.3-20 (USEPA, 1993). It is assumed that Year 0 is 2000.
- It is assumed that the construction activities for Alternative 3 would commence in 2003, when all OU and source control activities are complete. The construction for the Plainwell and Otsego impoundments are assumed in 2003 and 2004, respectively. The construction costs for Trowbridge Impoundment is equally distributed between 2005 and 2006.
- Engineering fees, project management and construction management are generally based on percentages shown on Exhibit 5-8 of the USEPA guidance document for feasibility study (OSWER 9355.0-075).
- A 20% contingency allowance is included to provide for unforeseen circumstances or variability in estimated areas, volumes, labor and material costs.

Component-Specific

A/B/C-1 Mobilization/demobilization (labor, material, equipment, etc.) is based on 3 percent of item (i.e., each impoundment) subtotal before mob/demob and general conditions.

A/B/C-2 General conditions refer to contractor overhead, project administration, and miscellaneous costs including health and safety and temporary construction trailer facility expenses. This is based on 1.5 percent of item subtotal before mob/demob and general conditions.

A/B/C-3 Clearing refers to clearing of vegetation and debris prior to river bank stabilization.

A/B/C-4 Access road costs assume the construction of a 16-foot wide roadway along both sides of the Kalamazoo River with additional ingress and egress, and turning areas as needed. The cost includes the restoration cost at the conclusion of the work.

A/B/C-5 River bank slope lengths were determined using field-transects, and slope area was obtained by multiplying average slope lengths by distances between adjacent transects. Bank stabilization methods generally consist of the installation of rip-rap or crushed concrete above and below water line. Native sand & gravel backfill will be placed in locally affected areas. Finally, topsoil will be placed on the disturbed areas and the restored areas revegetated (see below).

A/B/C-6 Bank stabilization measures that includes hard armor elements will generally be covered with soil and revegetated with native emergent herbaceous species at the water line and herbaceous plants and woody shrubs above the waterline.

A/B/C-7 An erosion control fence would be placed along the length of the river bank at each of the former impoundments. on both sides.

A/B/C-8 Stabilization activities will be performed by means of a barge where river depths allow, and where access from shore is not suitable. Costs associated with a barge/work platform include an excavator mounted on a stationary barge and transport barge for ferrying materials and personnel to the stationary barge.

D Visual observations are assumed to be performed 1 year after remedy implementation and then at 5-year intervals thereafter, where the observation event will correspond with the occurrence of the NCP-required 5-year review.

E Post-remedy care and maintenance are assumed to be performed 1 year after remedy and then at 5-year intervals thereafter for a period of 30 years post-remedy. It is assumed that the bank stabilization activities will be completed in Year 2006. So, post-remedy care and maintenance will begin from Year 2007. Maintenance costs were determined assuming that 5 percent of the 20 miles of stabilized bank will require repair work during each maintenance event.

F Institutional controls and monitoring program will begin in Year 2003 at the start of remedy implementation activities and continue for 30 years post-implementation to Year 2037. This will involve water column, sediment and biota advisory monitoring every five years and biota trend monitoring every 30 years. In addition, KALSIM model will be updated every five years.

TABLE 4-4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 4 - RIVER-WIDE CAPPING OF SUBMERGED SEDIMENT, BANK STABILIZATION AT THE FORMER IMPOUNDMENTS, INSTITUTIONAL CONTROLS, AND MONITORING

SUMMARY OF CAPITAL COSTS

Item No.	Description	Quantity	Unit	Unit Cost (rounded)	Item Cost (rounded)
A	**Submerged sediment containment**				
	1 Mobilization/demobilization	1	lump sum	$18,314,000	$18,314,000
	2 General conditions	1	lump sum	$9,157,000	$9,157,000
	3 Clearing	280,000	linear foot	$21	$5,880,000
	4 Develop and restore access areas	40	each	$200,000	$8,000,000
	5 Develop and restore access roads	409,000	square yard	$27	$11,043,000
	6 Erosion control (silt fence and curtain)	1	lump sum	$10,000,000	$10,000,000
	7 Cap material				
	Sand	14,000,000	cubic yard	$35	$490,000,000
	Gravel/Armoring	530,000	cubic yard	$55	$29,150,000
	Geotextile	7,000,000	square yard	$5	$35,000,000
	8 Barge/work platform	400	month	$53,500	$21,400,000
	SUBTOTAL				$637,944,000
	Engineering fees/project management (8%)				$51,036,000
	Construction management (6%)				$38,277,000
	Contingency (bid and scope) (30%)				$191,383,000
				TOTAL (YEARS 5 THROUGH 44):	$918,640,000
				PRESENT VALUE:	$218,299,000
B	**Bank stabilization**				
	SAME AS ALTERNATIVE 3				
	1 Plainwell Impoundment (2003)				$8,037,000
	2 Otsego Impoundment (2004)				$9,159,000
	3 Trowbridge Impoundment (2005 & 2006)				$26,144,000
				TOTAL (YEARS 3 THROUGH 6):	$43,340,000
				PRESENT VALUE:	$31,579,000
				TOTAL CAPITAL COST:	$961,980,000
				PRESENT VALUE:	$249,878,000

(See notes on page 3.)

TABLE 4-4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 4 - RIVER-WIDE CAPPING OF SUBMERGED SEDIMENT, BANK STABILIZATION AT THE FORMER IMPOUNDMENTS, INSTITUTIONAL CONTROLS, AND MONITORING

SUMMARY OF O&M COSTS

Item No.	Description	Quantity	Unit	Unit Cost (rounded)	Item Cost (rounded)
C	**Observation, care and maintenance of cap** (YEARS 6 THROUGH 75)				
	1 Cap maintenance, Years 6-15 (1% of cap cost in the 1st 10 years of construction)	10	annual	$2,297,000	$22,970,000
	2 Cap maintenance, Years 16-25 (1% of cap cost in the 1st 20 years of construction)	10	annual	$4,593,000	$45,930,000
	3 Cap maintenance, Years 26-35 (1% of cap cost in the 1st 30 years of construction)	10	annual	$6,890,000	$68,900,000
	4 Cap maintenance, Years 36-45 (1% of overall cap cost)	10	annual	$9,186,000	$91,860,000
	5 30 additional years of maintenance following completion, Years 46-75 (1% of overall cap cost)	30	annual	$9,186,000	$275,580,000
	6 Reporting (Years 6-75)	70	annual	$10,000	$700,000
	SUBTOTAL (ALL YEARS)				$505,940,000
	Engineering fees/project management (8%)				$40,475,000
	Construction management (6%)				$30,356,000
	Contingency (bid and scope) (30%)				$151,782,000
				TOTAL (YEARS 6 THROUGH 75):	$728,553,000
				PRESENT VALUE:	$40,824,000
D	**Observation, care and maintenance of the stabilized banks** SAME AS ALTERNATIVE 3 (YEARS 7 THROUGH 37)				$15,986,000
				TOTAL (YEARS 7 THROUGH 37):	$15,986,000
				PRESENT VALUE:	$4,491,000
E	**Institutional controls and monitoring** (YEARS 3 THROUGH 75)				
	1 Water column sampling	16	one event/5-years	$331,000	5,296,000
	2 Sediment sampling	16	one event/5-years	$249,000	3,984,000
	3 Biota sampling and monitoring - advisory	16	one event/5-years	$398,000	6,368,000
	4 Biota sampling and monitoring - trend	25	one event/3-years	$143,000	3,575,000
	5 KALSIM model updates	16	one event/5-years	$540,000	$8,640,000
				TOTAL (YEARS 3 YHROUGH 75):	$27,863,000
				PRESENT VALUE:	$5,301,000
				TOTAL O&M COSTS:	$772,402,000
				PRESENT VALUE:	$50,616,000
				GRAND TOTAL COST:	$1,734,382,000
				GRAND TOTAL PRESENT WORTH COST:	$300,494,000

(See notes on page 3.)

TABLE 4-4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 4 - RIVER-WIDE CAPPING OF SUBMERGED SEDIMENT, BANK STABILIZATION, AT THE FORMER IMPOUNDMENTS, INSTITUTIONAL CONTROLS AND MONITORING

General

- All costs include material and labor, unless otherwise noted.
- Costs do not include legal fees, permitting, obtaining access, negotiations, or agency oversight.
- Unit costs are in 2000 dollars and are estimated from standard estimating guides (e.g. Means Site Work and Landscape Cost Data, vendors, professional judgement and experience from other similar projects).
- Costs based on current site information and project understanding. This may change following collection of additional data and/or receipt of Agency input and actual project design.
- Present worth is estimated based on a 7 percent (%) beginning-of-year discount rate (adjusted for inflation) in accordance with USEPA policy directive entitled "Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis," OSWER Directive No. 9355.3-20 (USEPA, 1993).
- Cost estimates are generally developed based on the USEPA guidance document "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study," EPA 540-R-00-002 (OSWER 9355.0-75) dated July 2000.
- It is assumed that the construction activities for capping would commence in 2005 and continue for a period of 40 years thereafter. Bank stabilization activities would occur between Years 2003 and 2006, as discussed under Alternative 3. Care and maintenance for capping would commence in Year 2006 and continue to 2075, that is 30 years following overall completion of this project.
- Engineering fees, project management and construction management are assumed to be 3, 5 and 6% of the total cost before fees, respectively. A lower percentage for engineering fees is assumed due to the size of this project.
- A 30% contingency allowance is included to provide for unforeseen circumstances or variability in estimated areas, volumes, labor and material costs.

Component-Specific

A1 Mobilization/demobilization (labor, material, equipment, etc.) is based on 3 percent of item subtotal before mob/demob and general conditions.

A2 General conditions refer to contractor overhead, project administration, and miscellaneous costs including health and safety and temporary construction of trailer facility expenses. This is based on 1.5 percent of item subtotal before mob/demob and general conditions.

A3 Clearing refers to clearing of vegetation and debris prior to access road construction and bank stabilization.

A4 Access area development includes clearing and preparation of equipment and material staging/handling areas. Restoration includes the removal and disposal of gravel, fill replacement, where necessary, followed by topsoil application and vegetation.

A5 Assumes the construction and restoration of a 16-foot wide roadway along one side of the river for all reaches of the river but the former impoundments up to River Mile 43 in Lake Allegan. It is assumed that construction in Lake Allegan will be primarily utilizing barge mounted operations. Access roads within the former impoundments are considered as part of bank stabilization activities discussed under Alternative 3.

A6 Erosion control will involve the use of three layers of silt curtains placed across the river and immediately downstream of the work area.

A7 Two feet of sand will be placed in the current and former impoundments and 18 inches of sand overlain by 6 inches of gravel in the in-between stretches. A layer of geotextile will underlie the cap in 50 percent of the Site area. These costs include purchase, haul, stockpile maintenance and placement.

A8 Construction activities will be performed from a barge where river depths allow and shore access is unsuitable.

B Bank stabilization cost is same as Alternative 3 and presented in Table 4-3.

C Cap maintenance cost is spread over a period of 70 years (Years 6 through 75). The annual cap maintenance cost at a given time is estimated based on 1% of the portions of the cap constructed in successive 10-year periods until the cap is fully constructed, and 1% of the overall cap cost thereafter.

D Maintenance cost for the stabilized banks is same as Alternative 3 and presented in Table 4-3.

E Institutional controls and monitoring program will begin in Year 2003 at the start of remedy implementation activities and continue for 30 years post-implementation to Year 2075. This will involve water column, sediment and biota-advisory monitoring every five years and biota-trend monitoring every 3 years. In addition, KALSIM model will be updated every five years.

TABLE 4-5

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILTY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 5 - DREDGING OF SUBMERGED SEDIMENTS WITH UPLAND CONFINED DISPOSAL

SUMMARY OF CAPITAL COSTS

Item No.	Remedial Component	Quantity	Units	Unit Cost (Rounded)	Item Cost (Rounded)
1	**Construction**				
	Mobilization	1	lump sum	$4,457,000	$4,457,000
	General Conditions	1	lump sum	$3,342,000	$3,342,000
	Project Insurance	1	lump sum	$2,229,000	$2,229,000
	Construction Trailers	1	lump sum	$45,000	$45,000
	Clearing	105,000	linear foot	$21	$2,205,000
	Access road construction/restoration	247,000	square yard	$27	$6,669,000
	CDF Land lease or purchase	1,203	acre	$8,000	$9,624,000
	CDF clearing & grubbing	1,203	acre	$7,700	$9,263,000
	CDF bedding	1,914,650	cubic yard	$20	$38,293,000
	CDF exterior dikes	2,384,467	cubic yard	$15	$35,767,000
	CDF interior dikes	2,448,467	cubic yard	$15	$36,727,000
	CDF liner, bottom & walls	51,694,000	square foot	$0.50	$25,847,000
	CDF piping	1	lump sum	$6,151,000	$6,151,000
	CDF monitoring wells	54	wells	$1,000	$54,000
	WTF site preparation & paving	72,600	square yard	$25	$1,815,000
	WTF coagulation/flocculation/sedimentation	1	lump sum	$9,186,000	$9,186,000
	WTF multimedia filters	1	lump sum	$6,632,000	$6,632,000
	WTF carbon adsorption	1	lump sum	$5,540,000	$5,540,000
	WTF control buildings (3)	6,000	square foot	$70	$420,000
	WTF misc pumps, piping & electrical	1	lump sum	$4,719,000	$4,719,000
	Bank stabilization & habitat enhancement	1	lump sum	$23,885,000	$23,885,000
	SUBTOTAL				$232,870,000
	Engineering/Project Management				$18,630,000
	Construction Management (6%)				$13,972,000
	Contingency (20%)				$46,574,000
				TOTAL:	$312,046,000
				PRESENT VALUE:	$196,734,000
2	**Field Execution**				
	Dredging mobilization	1	lump sum	$17,187,000	$17,187,000
	General Conditions	1	lump sum	$15,475,000	$15,475,000
	Project Insurance	1	lump sum	$10,318,000	$10,318,000
	Construction Trailers	1	lump sum	$287,000	$287,000
	Dredges, barges, pumps and boats	23	year	$2,636,957	$60,650,000
	Dredge, boat and pump fuel use	23	year	$3,237,478	$74,462,000
	Dredge labor	23	year	$4,469,783	$102,805,000
	Dredge pipelines	23	year	$2,057,870	$47,331,000
	Silt Curtains, reefing and anchoring	23	year	$438,522	$10,086,000
	Turbidity monitoring stations	23	year	$1,189,783	$27,365,000
	Shoreline protection	1	lump sum	$57,737,000	$57,737,000
	Operate CDF - labor	23	year	$2,332,391	$53,645,000
	CDF & WTF maintenance	23	year	$7,351,348	$169,081,000
	WTF chemicals	98,870	m gal	$1,500	$148,305,000
	WTF filter media	98,870	m gal	$200	$19,774,000
	WTF activated carbon	98,870	m gal	$1,860	$183,898,000
	Operate WTF - labor	23	year	$3,498,522	$80,466,000
	SUBTOTAL				$1,078,872,000
	Engineering/Project Management				$53,943,000
	Construction Management (6%)				$64,731,000
	Contingency (20%)				$215,775,000
				TOTAL:	$1,413,321,000
				PRESENT VALUE:	$530,612,000

(See notes on page 3.)

TABLE 4-5

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILTY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 5 - DREDGING OF SUBMERGED SEDIMENTS WITH UPLAND CONFINED DISPOSAL

SUMMARY OF CAPITAL COSTS (CONT'D)

Item No.	Remedial Component	Quantity	Units	Unit Cost (Rounded)	Item Cost (Rounded)
3	**Decommissioning & Closure**				
	Mobilization - 3	1	lump sum	$11,845,000	$11,845,000
	General Conditions	1	lump sum	$8,883,000	$8,883,000
	Project Insurance	1	lump sum	$5,922,000	$5,922,000
	Construction Trailers	1	lump sum	$15,000	$15,000
	Decommission water treat facilities	1	lump sum	$11,325,000	$11,325,000
	CDF top liner	51,694,000	square foot	$0.50	$25,847,000
	CDF cover material	5,743,960	cubic yard	$25	$143,599,000
	CDF 2% graded cap	16,456,280	cubic yard	$25	$411,407,000
	SUBTOTAL				$618,843,000
	Engineering/Project Management				$49,507,000
	Construction Management (6%)				$37,130,000
	Contingency (20%)				$123,769,000
				TOTAL:	$829,249,000
				PRESENT VALUE:	$97,982,000
				TOTAL CAPITAL COST:	$2,552,230,000
				PRESENT VALUE:	$824,810,000

SUMMARY OF O&M COSTS

4	**Annual Costs**	Years	Annual	Total	Present Worth
	Bathymetric surveys	(2005 - 2028)	$50,000	$1,200,000	$437,000
	Confirmation sampling and analyses	(2005 - 2033)	$832,000	$24,128,000	$7,793,000
	Bank observation	(2017 - 2051)	$32,000	$1,120,000	$140,000
•	Bank maintenance	(2017 - 2051)	$424,743	$14,866,000	$1,863,000
	Monitoring - biota	(2006 - 2058)	$137,472	$7,286,000	$1,361,000
	Monitoring - water & sed	(2006 - 2058)	$126,943	$6,728,000	$1,257,000
	KALSIM model update	(2006 - 2058)	$118,189	$6,264,000	$1,170,000
	CDF & groundwater monitoring - A	(2007 - 2058)	$8,808	$458,000	$81,000
	CDF & groundwater monitoring - B	(2007 - 2058)	$12,808	$666,000	$118,000
	CDF & groundwater monitoring - C	(2007 - 2058)	$21,596	$1,123,000	$199,000
	SUBTOTAL ANNUAL				$1,764,558
	SUBTOTAL ANNUAL ALL YEARS				$63,839,000
	SUBTOTAL ANNUAL PRESENT WORTH ALL YEARS				$14,419,000
				GRAND TOTAL COST:	**$2,618,455,000**
				GRAND TOTAL PRESENT WORTH COST:	**$839,747,000**

(See notes on page 3.)

TABLE 4-5

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILTY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 5 - DREDGING OF SUBMERGED SEDIMENTS WITH UPLAND CONFINED DISPOSAL

NOTES/ASSUMPTIONS

- All costs include material and labor, unless otherwise noted.
- Costs do not include legal fees, permitting, obtaining access, negotiations, or agency oversight.
- Unit costs are in 2000 dollars and are estimated from standard estimating guides (e.g. Means Site Work and Landscape Cost Data, vendors, professional judgement and experience from other similar projects).
- Costs based on current site information and project understanding. This may change following collection of additional data and/or receipt of Agency input and actual project design.
- Cost estimates are generally developed based on the USEPA guidance document "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study," EPA 540-R-00-002 (OSWER 9355.0-75) dated July 2000.
- Present worth is estimated based on a 7 percent (%) beginning-of-year discount rate (adjusted for inflation) in accordance with USEPA policy directive entitled "Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis," OSWER Directive No. 9355.3-20 (USEPA, 1993) It is assumed that Year 0 is 2000.
- Engineering fees, project management and construction management are generally based on percentages shown on Exhibit 5-8 of the USEPA guidance document for feasibility study (OSWER 9355.0-075).
- A 20% contingency allowance is included to provide for unforeseen circumstances or variability in estimated areas, volumes, labor and material costs.

Specific:

- Mobilization/demobilization is a lump sum based on project size.
- General conditions refer to contractor overhead, and miscellaneous costs such as health and safety and construction trailer facility. Cost is a lump sum based on project size.
- Labor prices in accordance with Prevailing Rate Schedule, Kalamazoo Co., 1/1/2000 at 40hrs/wk/shift straight time and 14hrs overtime/wk/shift.
- Access area development includes clearing and preparation of equipment and material staging/handling areas. Restoration includes the removal and disposal of gravel, fill replacement, where necessary, followed by topsoil and vegetation.
- Access road construction assumes construction and restoration of a 16-foot wide roadway along both sides of the former impoundments, along one side of the in-between stretches and as needed to access the current impoundments, as further described in Alternatives 3 and 4 .
- Bank Stabilization costs as described for Alternatives 3 and 4, including components for Plainwell, Otsego, and Trowbridge impoundments.
- Dredging by hydraulic cutterhead dredge, assuming 600 cy/day production when dredging in the Kalamazoo River and 2000 cy/day production when dredging in Lake Allegan. A second overdredge of a 6-inch layer is assumed for all areas.
- Dual layer vinyl coated polyester silt curtain includes reefing and anchoring. It is assumed that 3800 linear feet will be replaced yearly. Silt curtain based on Elastec quotation, 9/98 escalated to 1/00.
- Five real-time turbidity monitoring stations are used for each dredging segment. Fixed monitoring stations are constructed of 6-in steel piling for each dredging segment, and removed after dredging. It is assumed that turbidity sensors will be replaced every 90,000 cy of dredging.
- Sheet piling will be placed along certain stretches to protect onshore facilities from dredging disturbance. It is assumed that this will be required along 10 percent of the shoreline.
- Cost of boats are amortized at 7.0% for 10-year life.
- Boat consumes total energy of 35 HP at Engine Fuel Factor (EFF) of 0.042 and fuel price of $1.80/ gal, for fuel costs of $2.65 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $0.265 per hr or $3.71 per day, for total fuel costs of $30 per day.
- 6 miles avg. pipeline reach
- First-pass dredging of Kalamazoo River segments at: 60 cy/hr; 10 hrs/day; 6 days/wk; 4 wk/mo; 10 mo/yr, 2400 hrs/yr; or 144,000 cy/yr, with in situ solids = 77%; dredge solids = 5%; dredge slurry pumping rate = 12.9 cfs during 10-hr/day.
- 13" Cutterhead Dredge is assumed for first pass on the Kalamazoo River, with costs amortized at 7.0% for 15-year life.
- 13" Cutterhead Dredge consumes total energy of 2630 HP at EFF of 0.042 and fuel price of $1.80/ gal, for fuel costs of $199 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $19.9 per hr or $279 per day, for total fuel costs of $2269 per day.
- Three 13-inch booster pumps consume total energy of 311 HP at EFF of 0 042 and fuel price of $1.80/ gal, for fuel costs of $24 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $2.4 per hr or $34 per day, for total fuel costs of $274 per day.
- Second-pass dredging of Kalamazoo River segments at. 60 cy/hr, 10 hrs/day, 6 days/wk; 4 wk/mo; 10 mo/yr; 2400 hrs/yr; or 144,000 cy/yr, with in situ solids = 77%; dredge solids = 2.5%; dredge slurry pumping rate = 26.2 cfs during 10-hr/day.
- 18" Cutterhead Dredge is assumed for second pass on the Kalamazoo River, with costs amortized at 7.0% for 15-year life.
- 18" Cutterhead Dredge consumes total energy of 4148 HP at EFF of 0.042 and fuel price of $1 80/ gal, for fuel costs of $314 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $31 4 per hr or $440 per day, for total fuel costs of $3580 per day.
- Three 18-inch booster pumps consume total energy of 630 HP at EFF of 0.042 and fuel price of $1.80/ gal, for fuel costs of $48 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $4.80 per hr or $67 per day, for total fuel costs of $547 per day.
- First-pass dredging of Lake Allegan at: 200 cy/hr, 10 hrs/day; 6 days/wk; 4 wk/mo; 10 mo/yr, 2400 hrs/yr, or 480,000 cy/yr, with in situ solids = 77%; dredge solids = 5%; dredge slurry pumping rate = 43 cfs during 10-hr/day, or two dredges, each at 21.5 cfs dredge slurry pumping rate.
- Two 18" Cutterhead Dredges are assumed for first pass on Lake Allegan, with costs amortized at 7.0% for 20-year life.
- Two 18" Cutterhead Dredges consume total energy of 8296 HP at EFF of 0.042 and fuel price of $1.80/ gal, for fuel costs of $628 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $62.80 per hr or $879 per day, for total fuel costs of $7159 per day.

TABLE 4-5

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILTY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 5 - DREDGING OF SUBMERGED SEDIMENTS WITH UPLAND CONFINED DISPOSAL

- Six 18-inch booster pumps consume total energy of 1035 HP at EFF of 0.042 and fuel price of $1.80/ gal, for fuel costs of $78 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $7.80 per hr or $109 per day, for total fuel costs of $889 per day.
- Second-pass dredging of Lake Allegan at: 200 cy/hr; 10 hrs/day; 6 days/wk; 4 wk/mo; 10 mo/yr; 2400 hrs/yr; or 480,000 cy/yr, with in situ solids = 77%; dredge solids = 2.5%; dredge slurry pumping rate = 87.4 cfs during 10-hr/day, or two dredges, each at 43.7 cfs dredge slurry pumping
- Two 24" Cutterhead Dredges are assumed for second pass on Lake Allegan, with costs amortized at 7.0% for 25-year life.
- Two 24" Cutterhead Dredges consume total energy of 12410 HP at EFF of 0.042 and fuel price of $1.80/ gal, for fuel costs of $938 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $93.80 per hr or $1313 per day, for total fuel costs of $10,693 per day.
- Six 24-inch booster pumps consume total energy of 2099 HP at EFF of 0.042 and fuel price of $1.80/ gal, for fuel costs of $159 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $15.90 per hr or $223 per day, for total fuel costs of $1813 per day.
- CDF area requirement is based on achieving long-term solids content of 47% w/w in facilities with 20-ft ultimate height. Three facilities are anticipated, with total containment volume of 25.3 million cy. Side slopes of 1:3 add additional area requirements, in addition to adjacent facilities for water treatment.
- CDF sizing is in accordance with Engineer Manual 1110-2-5027, "Engineering and Design, Confined Disposal of Dredged Material," USACE (30 Sep 1987).
- CDFs are assumed to contain a sand bedding of 1-ft, underdrains and polyethylene lining, prior to commencement of operation. Sizing of the CDFs assume 8 internal dikes will be constructed to facilitate operation and consolidation of sediment.
- Water treatment for overflow of dredge water from the CDF consists of flocculation, sedimentation, dual-media filtration and activated carbon adsorption. Discharge is to the Kalamazoo River or Lake Allegan. Treatment facilities are located adjacent to each of the three CDFs. Unit costs are based on experience at the Fox River SMU 56/57, with elimination of neutralization chemical costs. Flocculation and sedimentation assume 60 min. detention, filtration facilities are assumed to be loaded at 2.0 gpd/sf, and carbon contactors assume empty bed contact time of
- Control building of 1500 square ft to be constructed for each WTF.
- Closure of completed CDFs, after five years of final consolidation, would consist of a polyethylene membrane, one foot of soil cover and a 2%-sloped soil cap for runoff control.
- Bathymetric surveys are performed annually during dredging to confirm effectiveness.
- Confirmation Sampling includes analyses and QA/QC for in-situ sediments, waters and residuals for dredging and water treatment operations.
- Construction oversight includes project management and daily reports.
- Engineering fees are based on 8% of the construction subtotal cost or 5% of operational costs during field execution.
- Contingency is based upon 20% of the construction subtotal cost.
- Present worth dredging and disposal cost assumes costs are spread evenly over the duration of each program segment, at a 7% discount rate.
- Present worth cost includes institutional controls and monitoring. Samples for Advisory Monitoring of Biota are taken at year 1, then every 5 years until 30 years after completion of dredging. Samples for Trend Monitoring of Biota are taken at year 1, then every 3 years until 30 years after completion of dredging. Water and sediment samples are taken at year 1, then every 5 years until 30 years after completion of dredging. KALSIM model updates are performed at year 1, then every 5 years until 30 years after completion of dredging.
- Annual costs for maintenance of restored impoundments as developed for Alternative 3.
- CDF monitoring consists of sampling and analyses of perimeter monitoring wells for 52 years.
- Total present worth cost is the sum of costs for dredging, disposal, water treatment, institutional controls, and monitoring.

Figures

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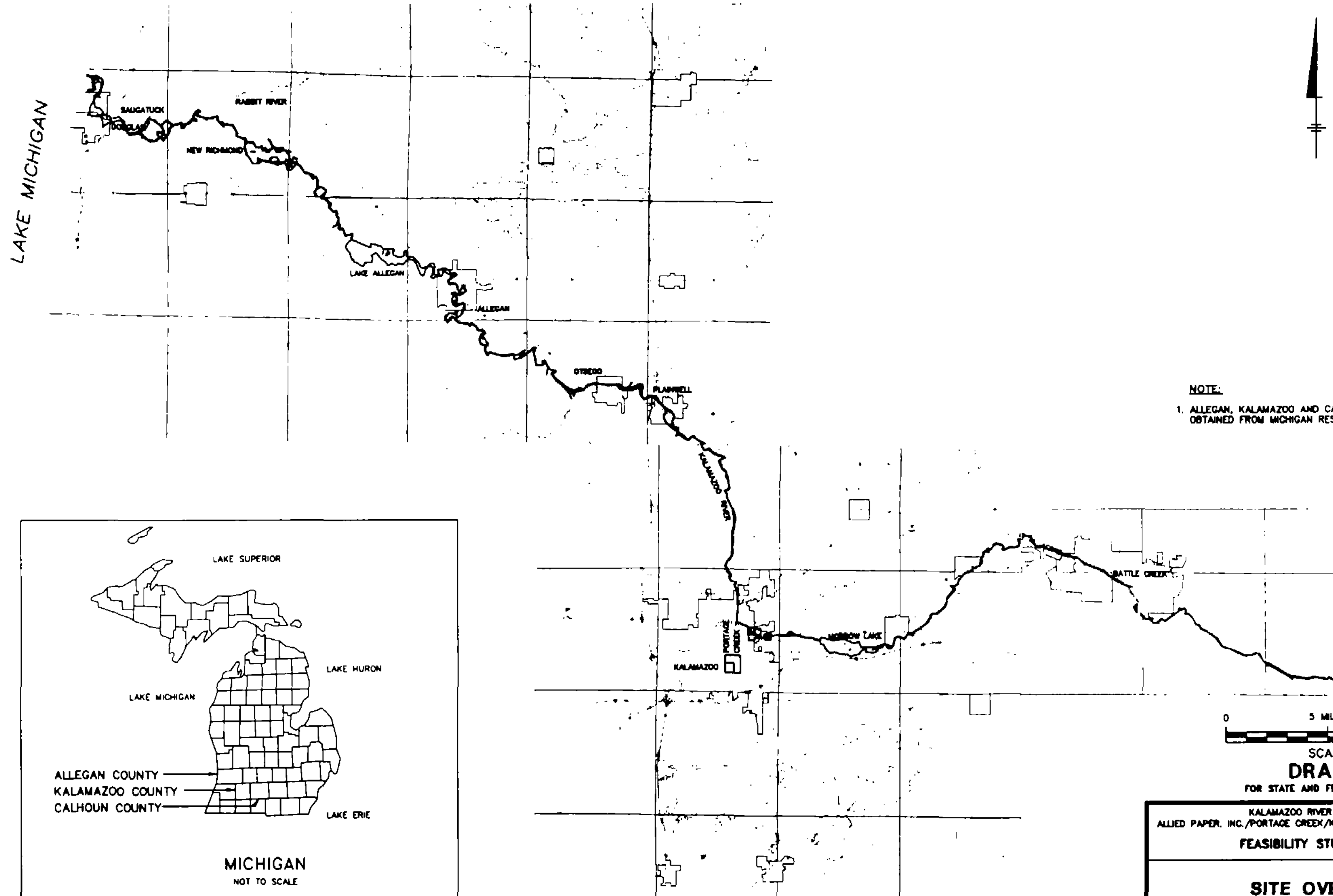


NOTE:

1. ALLEGAN, KALAMAZOO AND CALHOUN COUNTY MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEM.

0 5 MILES 10 MILES

SCALE

DRAFT

FOR STATE AND FEDERAL REVIEW

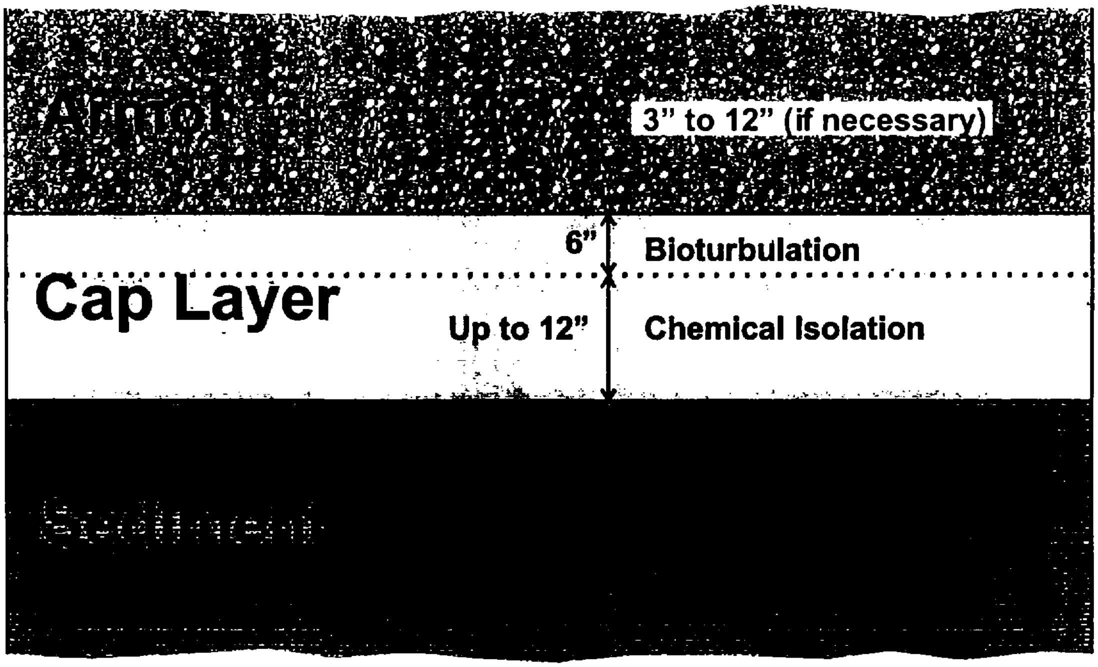
KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT

SITE OVERVIEW

BBL BLASLAND, BOUCK & LEE, INC.
engineers & scientists

FIGURE 1-1



DRAFT
FOR STATE AND FEDERAL REVIEW

KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT

CONCEPTUAL CAP/COVER CONFIGURATION

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FIGURE **3-1**

9/00 D54 LAS YCC
64524620/64524G01.cdr

Appendices

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Appendix A

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Bank Conditions in the Kalamazoo River

Appendix A – Bank Conditions in the Kalamazoo River

1.0 Characterization of the Kalamazoo River

This appendix characterizes the Kalamazoo River, focusing on a preliminary assessment of the riverbanks and identification of possible obstructions to the implementation of remedial alternatives.

1.1 General Conditions

Aerial photographs from April 1991 (Lockwood Mapping, Inc., 1991), April 1999 (Air Land Surveys, Inc., 1999), and November/December 1999 (Lockwood Mapping, Inc., 1999) were reviewed to obtain general information on the Kalamazoo River between Kalamazoo and Lake Allegan. This included identifying 1) structures and features located on the banks or crossing the river including buildings (industrial and residential), roadways, bridges, rail trusses, overhead cable lines, etc., 2) the channel type (i.e., straight, sinusoidal, or braided), and 3) tree coverage. The Kalamazoo River between Morrow Dam and Lake Allegan Dam is shown in Figures 1 through 8.

The Kalamazoo River traverses a large outwash plain with natural soils that are predominantly sands, gravels, and cobbles. This is evident in areas of exposed banks and from the numerous local gravel mines. For the most part, the Kalamazoo River is characterized by a single sinusoidal channel with a few straight and braided river reaches. The width of the main river ranges from 50 to 400 feet but is typically 100 to 200 feet. The river widens in impounded areas, where it ranges between 400 and 2,000 feet. The width of the secondary channels in the braided reaches and around island formations ranges between 20 and 100 feet. The river is generally very shallow with water depths ranging between 1 and 8 feet in the main river. Some of the areas in the impoundments are not navigable using a small boat.

Most of the shoreline is characterized by low to dense tree/shrub growths, some of which grow in the water. Tilted and fallen trees and overhanging branches are also evident along the entire river. The floodplains contain marsh-type vegetation including grass, shrubs, and trees. Some of these marshes contain tree growths that are 30 to 50 feet tall, indicating strong substrate foundation (i.e., older deposits). Tree growths in the banks generally represent older growths with the trees ranging from 30 to 50 feet in height. Several spot tree counts were performed along the banks of the Kalamazoo River to estimate tree density. The results of these tree counts are presented in the *Supplement to the Kalamazoo River Remedial Investigation/Feasibility Study* (RI/FS) (Blasland, Bouck & Lee, Inc. [BBL], 2000).

The riverbanks near cities and towns contain industrial and/or residential developments. Industrial/residential developments were mainly noted in the reaches between 0-6 miles in Kalamazoo (Mile-0 starting at the Morrow Dam and counting downstream), Miles 19-29 in Plainwell and Otsego, and Miles 40-47 in Allegan. The area surrounding Lake Allegan between Miles 47-52 has sparse residential developments with the remaining areas generally wooded and undeveloped. Riverfront developments that typically result in bulkheads, sheetpile, and riprap account for less than 2% of the total length of the riverbanks. Other shoreline structures include boat launches and docks (few and sparsely located), near-shore roadways, parking lots, yard areas, landfills, etc., which may present some dredging concern in terms of stability of these structures. The reaches between Miles 6 and 19 and Miles 28 and 40 represent "Free River Reaches," and gravel pits, farm lands, and undeveloped wooded areas are located near the riverbank in those reaches. These observations of the riverbanks between Kalamazoo and Lake Allegan are summarized in Table 1. The riverbanks were described as left or right bank looking downstream.

1.2 Current Bank Conditions

In June of 1998, representatives of BBL used a small boat to float substantial areas of the former Plainwell, Otsego, and Trowbridge impoundments. BBL returned in June of 2000 to conduct a boat-based investigation of the river between Kalamazoo and Lake Allegan. The June 2000 site visit included observations of riverbanks and floodplains in three distinct river reach types including Free River Reaches, Former Impoundments, and Current Impoundments. In addition, the site visit included observations around Lake Allegan and areas with channelized river reaches (i.e., river reaches that are stabilized using bulkheads, sheetpiles, riprap, etc.). A total of seven areas were evaluated, including:

- The river reach adjacent to the King Highway Landfill Operable Unit (Channelized River Reach) (Figure 2),
- The river reach immediately downstream of Verburg Park (Free River Reach) (Figure 3),
- The former Plainwell Impoundment between US 131 Bridge and Plainwell Dam (Former Impoundment) (Figure 5),
- The Otsego City Impoundment between Plainwell Dam and the Gun River Confluence (Current Impoundment) (Figure 5),
- The river reach (bend) immediately upstream of the Allegan City Line (Free River Reach) (Figure 7),

- The Allegan City Impoundment (Current Impoundment) (Figure 7), and
- Lake Allegan (Current Impoundment) (Figures 7 and 8).

Based on photographs, field observations, aerial photographs, and topographic information, three general categories of bank types were identified: Marsh Vegetation Bank Type, Tree/Shrub Vegetation Bank Type, and Channelized Bank Type. This characterization of the riverbanks takes into account factors such as vegetation cover and type of vegetation, geometry of the banks (i.e., bank slope), bank materials (i.e., sand and gravel, soft sediments, etc.), and relative location of water level (defined as the water surface elevation at average flow conditions). These bank types, along with other factors such as river velocity, concentrations of polychlorinated biphenyl (PCB) in the exposed sediment of the banks, thickness of the PCB-containing layer of exposed sediment, and thickness of sediments at the bank toe, form the basis of bank stabilization design concepts for the former Plainwell, Otsego, and Trowbridge impoundments discussed in Appendix B. Variations within each bank type were observed and are discussed below.

1.2.1 Former Impoundments

Within the MDNR-owned former impoundments, seven typical bank types were identified within two general categories: three marsh vegetation bank types and four tree/shrub vegetation bank types. These are discussed below. Photographs of the various bank types are shown in Figures 9 through 12. Bank stabilization concepts specific to these bank types are discussed in Appendix B. Note that these classifications are based on observations made during the site visits in 1998 and 2000. A more detailed delineation of the banks would be necessary prior to finalizing the bank stabilization design concepts discussed in Appendix B.

The three marsh vegetation bank types are described below.

Marsh Vegetation Bank Type 1: Root mat is at water level, and there is minimal erosion above the water line.

Marsh Vegetation Bank Type 2: Overhanging root mat is 6 inches to 3 feet above the water line, and the bank is eroded/recessed to a near vertical face.

Marsh Vegetation Bank Type 3: Steep (45 degrees or steeper) exposed face 1 foot to 3 feet high above sloping (3 horizontal: 1 vertical [3H:1V] to 10H:1V) spalled material, which is typically 6 inches to 1 foot above the waterline. The root mat is at the top of the exposed face with little overhang.

The four tree/shrub vegetation bank types are described below:

Tree/Shrub Vegetation Bank Type 1: Tree/shrub root mat, grass and leaf mold nearly to waterline. Slope usually flatter than 4H:1V.

Tree/Shrub Vegetation Bank Type 2: Tipping trees/dead stumps due to erosion of soil from below the tree roots. Slopes can locally be steeper than 4H:1V.

Tree/Shrub Vegetation Bank Type 3: Near vertical clay (1 to 3 feet thick) above exposed sand. Sand usually slopes down to water at 2H:1V or flatter. Steeper sand can occur on outside bank curve where more active erosion is occurring.

Tree/Shrub Vegetation Bank Type 4: Steep sand slopes that are partially bare.

A summary of bank lengths for each bank type encountered in each of the former impoundments is provided in Appendix B.

1.2.2 Current Impoundments and Free-Running River Reaches

In the river reaches outside the MDNR-owned former impoundments, eight typical bank types were identified within three general categories: three marsh vegetation bank types, four tree/shrub vegetation bank types, and one channelized bank type. The three marsh vegetation bank types, and four tree/shrub vegetation bank types are similar to those discussed in subsection 1.2.1. The other general category is the channelized bank type, which was observed in small portions of the river reaches. The three general categories are discussed below.

Marsh Vegetation Bank Type

Typically, these are low-lying banks, approximately 0 to 3 feet above the waterline. A discussion of the several variations of this bank type is provided in subsection 1.2.1.

Tree/Shrub Vegetation Bank Type

These comprise both low-lying marshy areas and steep high banks, and are similar to those discussed in subsection 1.2.1, except that the steep sand and gravel slopes (i.e., Tree/Shrub Vegetation Bank Type 4) were found to range in height from several feet to approximately 60 feet in places (much higher than those observed within the former impoundments). Some of the steep banks formed benches at the toe, and in other cases no benching was observed.

Channelized Riverbanks

Parts of the riverbanks adjacent to industrial areas, landfills, and bridges have been channelized using various methods including bulkheads, sheetpile, and riprap. This type of riverbank covers a small fraction of the total length (less than 2% of the total bank length). Figure 13 illustrates channelized riverbanks with riprap and concrete wall protection.

Note that these observations are based on site visits covering only a small fraction of the riverbanks, aerial photographs, and still photographs of the Site, and, while appropriately detailed for a feasibility assessment, are preliminary in nature. It is likely that many other bank types can be identified if a more detailed survey of the banks is undertaken.

2.0 Concerns Relating to Implementation of Remedial Alternatives

The following sections outline concerns related to the implementation of remedial alternatives that involve construction activities in and along the Kalamazoo River.

The major impacts due to dredging relate to bank stability, and stability of near shore structures.

2.1 Obstructions

Major obstructions that were observed include the following (refer to Table 1 for more details):

- Current dam structures. These include the Morrow Dam, Otsego City Dam, Allegan City Dam, and Lake Allegan Dam. There may be other smaller dam structures, including one noted in the west branch of the river around Plainwell.

- Former dam structures. These include the Plainwell, Otsego, and Trowbridge dams. In the early 1970s, these dams were permanently opened, dramatically lowering the water levels in these areas. Later in the 1980s the dams were dismantled to their sill levels. The dam sills, although in disrepair, remain in place retaining sediments and impounding 5 to 10 feet of water.

- Bridges. There are approximately 27 highway and 5 railway bridges located between Morrow Dam and Lake Allegan. Based on the field observations made in the river reaches outlined earlier, clearance (the distance between the bridge structure and water level at average flow conditions) was low, ranging from less than 3 feet to about 10 feet.

- Overhead cables. Cables were noted at several locations; however, they are few in number and typically allow for high clearance.

- Numerous fallen trees, snags, dead stumps in shallow water, overhanging branches and trees, etc.

- Trash and other debris on bank and mid-channel areas, particularly in urban areas.

No other obstructions were noted. The results of a diver-based survey of the bottom of Lake Allegan are presented in the *Supplement to the Kalamazoo River RI/FS* (BBL, 2000).

Based on the above information, it is expected that any water-based operation (i.e., snagging and clearing, dredging, capping, etc.) will have to take into account the nature of the current and former impoundments and the numerous bridge structures, most of which would be impassable for barge mounted equipment.

2.2 Bank Stability

The riverbanks in the former impoundment areas are unstable and contain active erosion areas as well as steep (1H:1V or steeper) and high riverbanks. Bank heights along the entire river vary from several feet to about 60 feet in some places. Many of the underwater slopes are in the range of 10H:1V to 15H:1V. Dredging at the toe of an already eroding bank or even a seemingly stable bank would likely induce slumping at the toe leading to increased erosion and possibly bank failures. This situation could be exacerbated if trees and vegetation from the slopes, which prevent surficial erosion, are cleared in order to provide access for the performance of bank-to-bank dredging. Based on the existing slope angles and the observed conditions of the banks, stable bank conditions will not be achieved if after dredging bank slopes are restored to 1H:1V to 2H:1V. This would mean cutting the banks flatter than 2H:1V slopes and/or adopting significant bank stabilization measures to stabilize the post-dredging (bank-to-bank) riverbanks at least to their present conditions.

In addition, dredging at the toe of existing structures (i.e., bulkheads, sheetpiles, riprap banks, boat launching areas, etc.) may present a concern to the stability of these structures. Caution and/or engineering controls will have to be exercised if dredging near these structures is deemed necessary.

2.3 Fallen Trees, Branches and Snags

The riverbanks along most of the river have dense tree and shrub growths down to the water line. Fallen trees, snags and overhanging branches are common. As a result, extensive clearing would be required to conduct any dredging project. Typical tree counts (1-inch diameter or greater) are presented in the *Supplement to the Kalamazoo River RI/FS.*

References

Blasland, Bouck & Lee, Inc. (BBL). 2000. *Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site – Supplement to the Kalamazoo River RI/FS* (Syracuse, NY: October 2000).

Lockwood Mapping, Inc. 1991. Aerial photography for the Kalamazoo River between Morrow Dam and Lake Allegan, flown in April 1991.

Lockwood Mapping, Inc. 1999. Aerial photography for the Kalamazoo River between Morrow Dam and Lake Allegan, flown in November and December 1999.

Air Land Surveys, Inc. 1999. Aerial photography for the Kalamazoo River between Morrow Dam and Lake Allegan, flown in April 1999.

Table

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
KALAMAZOO RIVER - SUMMARY OF BANK CONDITIONS KALAMAZOO TO LAKE ALLEGAN

River Mile[1]	Air Photo Number[2]	Structures and Features	Bank Conditions	Access[3]
0-1	R-1 FLT 2-15 (Nov 99) R-1 FLT 2-13 (Nov 99) Sheet 1 (Apr 91)	• Morrow Dam and a power plant are located at 0 River Mile The dam is approximately 1850 feet long (concrete and earth structure) The downstream (d/s) side (riverside) is also protected with bulkhead and riprap for a length of about 500 feet. • The Consumers Power Drive bridge crosses the river at 0.17 River Mile feet). The bridge is approximately 300 feet long. The river below is about feet wide • Overhead cables cross about 100 feet d/s of the bridge. • Two (2) boat launch areas/docks are located on the right bank (north) There are no other offshore or waterfront structures. • Roadways and highways pass along both banks. • Residential developments on parts of both banks	• River flows from east to west general direction • The channel is single and fairly straight. • The riverbanks have dense tree cover with some overhanging onto the • The width of the river ranges from 100 to 500 feet.	Good Possible from residential areas also from near the dam
1-2	R-1 FLT 2-13 (Nov 99) R-1 FLT 2-11 (Nov 99) Sheets 1/2 (Apr 91)	• The River Street bridge crosses the river at 1 2 River Miles The bridge is approximately 200 feet long The river below is about 150 feet wide. • Residential and industrial developments on both banks, some in proximity to the shore lines with grounds cleared of trees up to the shoreline. • King Highway passes along the right bank (north). Comstock Avenue passes along the left bank (south) • No offshore or waterfront structures.	• The river flows from east to west general direction. • The channel is single fairly straight with an oxbow island forming on the north bank. King Hwy passes through this island. • Shorelines on both banks are vegetated with moderate tree cover. Some overhanging onto the river • The width of the river ranges from 100 to 200 feet.	Good. Possible from nearby highways/ roadways, or residential/industrial areas
2-3	R-1 FLT 2-11 (Nov 99) R-1 FLT 2-9 (Nov 99) Sheets 2/3 (Apr 91)	• The Sprinkle Road bridge crosses the river at 2.16 River Miles. The bridge is approximately 280 feet long. The river below is divided into two channels, each about 100 feet wide • King Highway and railway pass along the right bank (north), and Comstock Avenue continues along the left bank (south) • Industrial developments on parts of both banks • Willow Boulevard/A-Site OU located near the end of this stretch. • No offshore or waterfront structures.	• The river flows from east to west general direction. • The channel is single fairly straight with an oxbow island forming near the west end on the north bank. King Hwy passes through this island. • Shorelines on both banks are vegetated with moderate tree cover Some overhanging onto the river Parts of the left bank (south) cleared for • The width of the river ranges from 100 to 200 feet.	Good. Possible from nearby highways/ roadways, or industrial areas
3-4	R-1 FLT 2-9 (Nov 99) R-1 FLT 2-7 (Nov 99) Sheet 3 (Apr 91)	• King Highway (M-96) continues on along the right bank then crosses the river near the King Highway Landfill OU at 3.40 River Miles. The bridge is approximately 250 feet long. The river below is about 200 feet wide • The right bank (north) is developed and contains the Georgia-Pacific Corporation Mill. Some of the facilities are in proximity to the shoreline. A pipeline appears to run along the bank in this facility The right bank within the property limit of Georgia-Pacific is protected by riprap, which has mature tree/shrub growths • The left bank (south) contains the Willow Boulevard/A-Site OU, and the King Highway Landfill OU These OUs are constructed near the edge of the water and the banks are cleared of trees and protected by ripraps and sheetpiles • A railway bridge crosses the river immediately d/s of King Highway Landfill OU at 3.9 River Miles. The bridge is approximately 200 feet long. The river below is about 100 feet wide.	• The river flows from east to west general direction. • The channel is single sinusoidal. • Shorelines on much of the areas are cleared with the remaining areas having low to moderate tree cover. Some overhanging onto the river • The width of the river ranges from 100 to 400 feet	Good Possible from nearby highways/ roadways, or OUs
4-5	R-1 FLT 4s-7 (Nov 99) R-1 FLT 5-26 (Nov 99) Sheets 3,4,7 (Apr 91)	• The Mills Street bridge crosses the river at 4 6 River Miles. The bridge is about 260 feet long and the river below is about 180 feet wide • The Kalamazoo Avenue (M-43) bridge crosses the river at 4.8 River Miles. The bridge is about 320 feet long and the river below is about 200 feet wide. King Highway continues to run parallel to the right bank (east). • A railway bridge crosses the river Immediately d/s of King Highway at 4.9 River Miles. The bridge is approximately 215 feet long The river below is about 150 feet wide • Largely industrial developments on both banks The right bank contains a railyard. The left bank has two riverfront parks (the Red Arrow and Riverview)	• At the end of this stretch the river turns north. • The channel is single sinusoidal. Portage Creek enters the river on the left bank (west) near the Kalamazoo Ave./M-43 bridge • For the most part, shorelines are vegetated with low to moderate tree cover. Some overhanging onto the river. Isolated areas (approximately 400 feet) in front of the railway bridge is cleared of trees • The width of the river ranges from 100 to 200 feet.	Limited. Possible from nearby highways/ roadways, or industrial areas. Access is rated as limited since four bridge structures cross the river within one river mile.

(See notes on page 7)

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
KALAMAZOO RIVER - SUMMARY OF BANK CONDITIONS KALAMAZOO TO LAKE ALLEGAN

River Mile[1]	Air Photo Number[2]	Structures and Features	Bank Conditions	Access[3]
5-6	R-1 FLT 5-26 (Nov 99) R-1 FLT 5-24 (Nov 99) Sheet 7 (Apr 91)	• The Gull Road bridge crosses at 5.1 River Miles. The bridge is approximately 270 feet long. The river below is about 150 feet wide. • An overhead cable line crosses at 5.3 River Miles. • The Paterson Street bridge crosses at 5.5 River Miles. The bridge is approximately 300 feet long. The river below is about 140 feet wide. • The Kalamazoo Water Reclamation Plant is located on the left bank (west) with a discharge point into the river. • Largely industrial developments on both banks. The left bank (west) contains a riverfront park (Verburg Park) with a lagoon that is connected to the river.	• The river flows to the north. • The channel is single sinusoidal. Spring Valley Creek enters the river on the right (east) bank at 5.9 River Miles. • Shorelines are vegetated with moderate tree cover. Some overhanging onto the river. Isolated areas near the bridge abutments are cleared and • The width of the river ranges from 100 to 150 feet.	Good/Limited Possible from nearby highways/ roadways, parks or industrial areas Access is rated as good near north end, and limited near south end.
6-7	R-1 FLT 5-24 (Nov 99) R-1 FLT 5-22 (Nov 99) Sheet 8 (Apr 91)	• Riverview Drive continues to run parallel to the right bank (east). • The Mosel Avenue bridge crosses at 6.5 River Miles. The bridge is approximately 270 feet long The river below is about 190 feet wide. • Overhead cable lines crosses the river near the Mosel Avenue bridge. • A rail track traverses on the left bank (west). • A railway bridge crosses at 6.7 River Miles, which is approximately 300 feet long and the river beneath is 300 feet wide. • Parts of both banks contain industrial developments with the remaining areas undeveloped.	• The river flows to the north. • The channel is single sinusoidal. • Shorelines are vegetated with low to moderate tree cover with some bare areas on the right bank (east). • The width of the river ranges from 50 to 300 feet.	Good/Limited. Possible from nearby highways/ roadways or industrial areas Access is rated as good near south end, and limited near north end as three bridges are located in proximity to each other
7-8	R-1 FLT 5-22 (Nov 99) R-1 FLT 5-20 (Nov 99) Sheets 8 and 9 (Apr 91)	• A railway bridge crosses at 7.2 River Miles, which is approximately 380 feet long and the river beneath is 320 feet wide. • Overhead cables cross the river immediately d/s of the railway bridge. • A treatment plant is located on the right bank (east) with a disposal point into the river (former Ft. James facility). • Parts of both banks contain industrial developments with the remaining areas undeveloped.	• The river flows to the north. • The channel is single sinusoidal with a large mid-channel island forming near the end of this stretch. • Shorelines have moderate tree cover. • The width of the river ranges from 50 to 300 feet.	Good/Limited Possible from nearby roadways that traverse the right bank. Generally good access with limited access to the south end due to bridges.
8-9 Free River Reaches	R-1 FLT 5-20 (Nov 99) R-1 FLT 5-18 (Nov 99) Sheet 9 (Apr 91)	• A rail track traverses on the left bank (west). • Gravel pits located west of the rail tracks on the left bank. • Gravel pits on the right bank (east) near the end of this stretch. • Overhead cables cross at 8 7 River Miles An inlet channel forms below the overhead cables on the left bank (west)	• The river flows to the north. • The channel is single sinusoidal with two oxbow islands forming between River Miles 8.5 to 9.0. • Shorelines have dense tree cover. • The width of the river ranges from 100 to 200 feet.	Good Possible from the gravel pits on the right bank
9-10 Free River Reaches	R-1 FLT 5-18 (Nov 99) R-1 FLT 5-16 (Nov 99) Sheets 9/10 (Apr 91)	• Rail tracks traverse along both banks. • A large gravel pit is located on the left bank (west) west of the rail tracks. • No offshore or water's edge structures.	• The river flows to the north. • The channel is single sinusoidal with an oxbow island forming near the north end. • Shorelines have dense tree cover. • Travis Creek enters the right bank (east) at 9.2 River Miles. Spring Brook enters at 9.9 River Miles. • The width of the river ranges from 100 to 200 feet.	Good. Possible from the gravel pits on the right bank.
10-11 Free River Reaches	R-1 FLT 4n-11 (Nov 99) R-1 FLT 4n-13 (Nov 99) Sheets 10/11 (Apr 91)	• Rail tracks traverse along both banks. • Several gravel pits located on either banks. • No offshore or water's edge structures.	• The river flows to the north • The channel is single and fairly straight with islands forming at locations. • Shorelines have dense tree cover. • The width of the river ranges from 190 to 320 feet in the main channel, 30 - 50 feet around the islands.	Good. Access possible from nearby D Avenue
11-12 Free River Reaches	R-1 FLT 4n-11 (Nov 99) R-1 FLT 4n-10 (Nov 99) R-1 FLT 5-10 (Nov 99) Sheet 11 (Apr 91)	• Rail tracks traverse along both banks. • D Ave bridge crosses at 11 3 River Miles, approximately 380 feet long. • Gravel pits on either banks. • Several nearshore building structures (a total of four locations on both banks) • No offshore or water's edge structures.	• The river flows to the north • The channel is single and fairly straight with islands forming at locations. Some of the channels around the islands are almost dry • Shorelines have low to dense tree cover. • The width of the river ranges from 200 to 400 feet in the main channel, 20 - 80 feet around the islands	Good. From near the roadway bridge.

(See notes on page 7)

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
KALAMAZOO RIVER - SUMMARY OF BANK CONDITIONS KALAMAZOO TO LAKE ALLEGAN

River Mile[1]	Air Photo Number[2]	Structures and Features	Bank Conditions	Access[3]
12-13 Free River Reaches	R-1 FLT 4n-6/8 (Nov 99) R-1 FLT 5-10 (Nov 99) Sheets 11/12 (Apr 91)	• Rail tracks traverse along both banks, but in proximity to the left bank • Several gravel pits are located on both banks. One of them on the east bank is dry during fall but flooded during spring. • No offshore or water's edge structures.	• The river flows generally to the north. • The channel is single sinusoidal. Two creek systems enter the river from the right bank (east). • Shorelines have low to dense tree cover • The width of the river ranges from 50 to 100 feet in the main channel.	Good From near the roadway bridge
13-14 Free River Reaches	R-1 FLT 6-15/17 (Nov 99) R-1 FLT 4n-6 (Nov 99) Sheets 12/13 (Apr 91)	• Rail tracks traverse along both banks. • Farm lands on both banks. • No offshore or water's edge structures.	• The river flows generally to the north. • The channel is single sinusoidal • A creek system enters the river from the right bank • Shorelines have moderate to dense tree cover. • The width of the river ranges from 50 to 200 feet in the main channel.	Good.
14-15 Free River Reaches	R-1 FLT 6-15 (Nov 99) Sheet 13 (Apr 91)	• Rail tracks traverse along both banks. • Farm lands on both banks. • No offshore or water's edge structures.	• The river flows generally to the northwest. • The channel is single sinusoidal with several islands forming in the • Two creek systems (one is Silver Creek) enter the river from the right bank (east). • Shorelines have low to moderate tree cover • The width of the river ranges from 50 to 200 feet in the main channel.	Good. Access possible from nearby farm roads
15-16 Free River Reaches	R-1 FLT 6-13 (Nov 99) Sheet 14 (Apr 91)	• Farm lands on both banks. • No offshore or water's edge structures. • Rail tracks pass along the left bank (west).	• The river flows to the northwest direction. • The channel is single sinusoidal with several oxbow islands forming. • Shorelines have low to moderate tree cover. • The width of the river ranges from 40 feet (around islands) and 80 to 150 feet in the main channel.	Good Access possible from nearby farm roads
16-17 Free River Reaches	R-1 FLT 6-11 (Nov 99) Sheets 14/15 (Apr 91)	• Farm lands on both banks • No offshore or water's edge structures. • A railway bridge crosses at 17.0 River Miles, approximately 200 feet wide. • Overhead cables cross at 16 9 River Miles	• The river flows to the northwest direction. • The channel is single sinusoidal. A creek enters the river from left bank (west). • Shorelines have low to moderate tree cover • The width of the river ranges from 50 to 150 feet in the main channel.	Good. Access possible from nearby farms
17-18 Free River Reaches	R-1 FLT 6-11 (Nov 99) R-1 FLT 6-9 (Nov 99) Sheet 15 (Apr 91)	• Farm lands on both banks • Douglas Avenue runs along the left bank (west) • Overhead cables cross at 18 River Miles. • No offshore or water's edge structures	• The river flows to the northwest direction. • The channel is single sinusoidal with islands forming at mid-channel • Shorelines have low to moderate tree cover, with some isolated cleared areas • The width of the river ranges from 100 to 170 feet in the main channel	Good Access possible from nearby farms.
18-20 Plainwell	R-1 FLT 9-10 (Nov 99) R-1 FLT 9-8 (Nov 99) Sheets 15/16 (Apr 91)	• At the beginning of this stretch is what appears to be the remnants of a structure (likely an old dam) located in the right channel. • There are four roadway bridges that cross the west branch at 18.64, 19 10, 19 30, and 19.40 River Miles. A railway bridge crosses the west branch at 19 50 River Miles. • There are two roadway bridges that cross the east branch at 19 16 (M-89), and 19 50 (Main Street) River Miles. A railway bridge crosses the east branch at 19.30 River Miles. • A dam-like structure is located in the west branch at 19.60 River Miles. • Overhead cables cross the east branch at two locations near the northwest end. • Both banks and the island have dense residential developments, with some farm lands near the southeast end. • One boat launch area located at 19.26 River Miles on the east channel.	• The river flows to the northwest direction. • The channel bifurcates and flows around the island of Plainwell • The west branch is channelized for a stretch of about 1150 feet between River Miles 19.30 and 19.50 on both banks (appears to be bulkheads and ripraps). • The east bank of west branch between 18.64 and 19 30 River Miles appear to have a riverfront walkway which may be protected by riprap. • Near the tip of the island, the left bank of the east branch is protected by what appears to be a concrete structure for about 650 feet • The remaining banks have low to moderate tree covers • Several islands form at the northwest end where the two branches join to form a single channel.	Good/Limited Access possible from several nearby roadways including the launch site by 10th Street bridge Access rated limited between River Miles 18 64 and 19.60 in the west branch, and between River Miles 19.10 and 19 50 in the east branch due to numerous bridge crossings Access is rated good in the remaining areas

(See notes on page 7)

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
KALAMAZOO RIVER - SUMMARY OF BANK CONDITIONS KALAMAZOO TO LAKE ALLEGAN

River Mile[1]	Air Photo Number[2]	Structures and Features	Bank Conditions	Access[3]
20-21 Former Plainwell Impoundment	R-1 FLT 9-6 (Nov 99) R-1 FLT 7-13 (Nov 99) Sheet 17 (Apr 91)	• Farm lands on right bank (east) to about Highway 131 bridge and past. • Plainwell WWTP on the left bank and an area under construction beside Hwy 131 bridge. • Hwy 131 bridge at 20.40 River Miles. The bridge is approximately 430 feet long. The river beneath is 250 feet wide. Abutments protected by nipraps. Mid-channel island beneath the bridge divides the channel into two • No offshore or water's edge structures.	• The river flows to the northwest direction, and turns to west near the Hwy 131 bridge. • The channel is single straight with wide floodplains. • Shorelines have low tree cover, with exposed impounded sediments (grass covered). • The width of the river ranges from 80 to 300 feet.	Good. Access possible from the treatment plant and possibly from near the bridge
21-22 Former Plainwell Impoundment	R-1 FLT 7-13 (Nov 99) R-1 FLT 8-13 (Nov 99) Sheet 18 (Apr 91)	• Farm lands on the right bank (north) up to Plainwell Dam. • Industrial developments on the left bank up to the Plainwell Dam. • Plainwell Dam located at 21.34 River Miles. • No offshore or water's edge structures.	• The river flows to the west. • The channel is single straight up to the dam and braided in front of the • Parts of the river banks and the floodplain areas appear to have been formed of exposed sediments. Banks are grass and/or tree/shrub covered. • The width of the river ranges from 100 to 200 feet. 20 to 40 feet around islands.	Good. Access possible from near the dam
22-23 Otsego City Impoundment	R-1 FLT 8-9/13 (Nov 99) R-1 FLT 8-11 (Nov 99) Sheets 18/19 (Apr 91)	• Railway and River Street pass along the right bank (north) • Residential areas adjacent to the roadway • No offshore or water's edge structures. • Gun River enters river on the right (north)	• The river flows to the west. • The channel is braided. Shallow water depth is expected. • River banks include floodplain areas of exposed sediments with grass, trees/shrub vegetation. • The width of the river ranges from 100 to 300 feet for the main channel and 20 to 50 feet for secondary channels.	Good Access possible from near the Plainwell Dam and from the roadway on the right bank
23-24 Former Otsego Impoundment	R-1 FLT 8-7 (Nov 99) R-1 FLT 8-9 (Nov 99) Sheet 19 (Apr 91)	• Otsego City Dam is located at 23.3 River Miles. • Farmer Street bridge crosses at 23.5 River Miles. • North Street bridge crosses at 23.8 River Miles. • Menasha Corporation and Rock-Tenn Co. are located on the right (north) bank. Other industrial developments on left (south) bank. • No offshore or water's edge structures.	• The river flows to the west. • The channel is single straight. • River banks include floodplain areas of exposed sediments with grass, tree/shrub vegetation up to the dam and moderate to dense tree covers d/s • The width of the river ranges from 100 to 400 feet for the main channel and 50 to 100 feet for secondary channels.	Good. Access possible from near the Otsego City Dam and from nearby industrial areas Access to D/S of Otsego City Dam is rated limited due to bridge crossings and the dam
24-25 Former Otsego Impoundment	R-1 FLT 8-7 (Nov 99) R-1 FLT 8-5 (Nov 99) Sheets 19/20 (Apr 91)	• M-89 bridge crosses at 25 River Miles, the bridge is approximately 320 feet long and the river below is about 200 feet wide. • Industrial developments on both banks, some close to the riverfront. • M-89 runs along left (south) bank and other roadways run along both • No offshore or water's edge structures.	• The river flows to the west. • The channel is single sinusoidal. • River banks has low to moderate tree cover. • The width of the river ranges from 150 to 200 feet.	Good. Access possible from near the Otsego WWTP or other industrial areas
25-26 Former Otsego Impoundment	R-1 FLT 8-5/8-3 (Nov 99) Sheets 20/21 (Apr 91)	• Mostly residential and some industrial developments on both banks. • SR 89 runs along right (north) bank and Jefferson Road runs along left (south) bank. • No offshore or water's edge structures.	• The river flows to the west. • The channel is single sinusoidal. • River banks have grass and/or tree/shrub (moderate density) covers • The width of the river ranges from 100 to 200 feet. • Pine Creek enters the left bank at 25.7 River Miles, and a large flooded area is formed behind Jefferson Road.	Good Access possible from Jefferson Road.
26-27 Former Otsego Impoundment	R-1 FLT 8-3 (Nov 99) R-1 FLT 11-23 (Nov 99) Sheets 21/22 (Apr 91)	• River Road runs along the left (west) bank. • The Otsego Dam is located at 26.7 River Miles. • Overhead cables cross immediately d/s of Otsego Dam. • Farm lands, residential, and undeveloped areas characterize both banks. • No offshore or water's edge structures.	• The river flows to the northwest. • The channel is single straight • River banks are mostly grassy (exposed sediments). • Mid-channel island formations immediately d/s of Otsego Dam • The width of the river ranges from 50 (around islands) to 300 feet.	Good Access possible from River Road and from near the dam
27-28 Former Trowbridge Impoundment	R-1 FLT 11-25 (Nov 99) R-1 FLT 11-23 (Nov 99) Sheets 22/23 (Apr 91)	• River Road runs along the left (west) bank. • Farm lands and undeveloped areas characterize both banks. • A trailer park is located on the right bank near the end of this stretch • No offshore or water's edge structures.	• The river flows to the northwest. • The channel is single sinusoidal. • River banks have low to moderate vegetation covers with some exposed areas (grassy areas) • Oxbow island formation near the end of this stretch • The width of the river ranges from 50 (around islands) to 250 feet.	Good Access possible from near Otsego Dam, River Road, and the trailer park.

(See notes on page 7)

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
KALAMAZOO RIVER - SUMMARY OF BANK CONDITIONS KALAMAZOO TO LAKE ALLEGAN

River Mile[1]	Air Photo Number[2]	Structures and Features	Bank Conditions	Access[3]
28-29 Former Trowbridge Impoundment	R-1 FLT 11-23 (Nov 99) Sheet 23 (Apr 91)	• Farm lands and undeveloped areas characterize the banks • No offshore or water's edge structures. • Lynx Golf Course adjacent to river.	• The river flows to the northwest. • The channel is single and very sinusoidal • River banks have low vegetation covers with some exposed areas (i.e., grassy areas) • The width of the river ranges from 100 to 200 feet.	Good. Access possible from River Road and the trailer park
29-30 Former Trowbridge Impoundment	R-1 FLT 11-23 (Nov 99) R-1 FLT 11-21 (Nov 94) Sheet 23 (Apr 91)	• River Road runs along the left (west) bank • Farm lands and undeveloped areas characterize the banks. • No offshore or water's edge structures	• The river turns to the west at about 29.8 River Miles • The channel is single and very sinusoidal • River banks have low vegetation covers with large exposed areas (grassy marsh areas). • The width of the river ranges from 100 to 200 feet.	Good Access possible from River Road
30-31 Former Trowbridge Impoundment	R-1 FLT 11-21 (Nov 99) R-1 FLT 12-24 (Nov 99) Sheet 25/24 (Apr 91)	• Trowbridge Dam is located at 31.3 River Miles, immediately d/s of this segment. • No offshore or water's edge structures. • Schnable Brook enters river on the right (north)	• The river flows to the west. • The channel is single with broad floodplain areas. The floodplain becomes exposed in November but goes underwater in April. • The floodplain areas are mainly exposed with marsh type vegetation (i.e., grass, reeds, small trees, etc.) The banks have low to moderate tree • The width of the river ranges from 200 to 300 feet.	Good. From Trowbridge Dam area
31-32 D/S of Former Trowbridge Dam	R-1 FLT 12-24 (Nov 99) R-1 FLT 12-22 (Nov 99) Sheet 26 (Apr 91)	• Trowbridge Dam is located at 31.3 River Miles. • 26th Street bridge is located at 31.5 River Miles, approximately 300 feet long and the river below is 190 feet wide. • Farm lands occupy both banks. • No offshore or water's edge structures.	• The river flows to the west. • The channel is single sinusoidal • The riverbanks have moderate to dense tree covers. • The width of the river ranges from 150 to 200 feet.	Good. From 26th Street bridge, Trowbridge Dam, or nearby farms.
32-33 Free River Reaches	R-1 FLT 12-22 (Nov 99) R-1 FLT 13S-22 Sheets 26/27 (Apr 91)	• Farm lands on both banks. • No offshore or water's edge structures	• Following a sharp bend the river turns to the north. • The channel is single and very sinusoidal. • The riverbanks have moderate to dense tree covers. • The width of the river ranges from 100 to 200 feet.	Good Access possible from nearby farms.
33-34 Free River Reaches	R-1 FLT 13s-22 (Nov 99) R-1 FLT 12-19 (Nov 99) Sheet 27 (Apr 91)	• Farm lands on both banks. Roadways connect the farms. • A couple of shed-like structures on the right (east) bank. • No offshore or water's edge structures	• River flows to the north and around a large island. • The riverbanks have moderate to dense tree covers • The width of the river ranges from 100 to 200 feet in the east branch, about 50 feet in the west branch.	Good Access possible from nearby farms
34-35 Free River Reaches	R-1 FLT 12-19 (Nov 99) R-1 FLT 12-17 (Nov 99) Sheets 27/28 (Apr 91)	• Farm lands on right (east) bank and undeveloped areas on left (west) bank • No offshore or water's edge structures.	• River flows to the northwest. • The river is single sinusoidal with some island formations. • The riverbanks have moderate to dense tree covers. • The width of the river ranges from 100 to 200 feet.	Good. Access possible from nearby roadways
35-36 Free River Reaches	R-1 FLT 12-17 (Nov 99) Sheet 28 (Apr 91)	• Williams Road bridge is located at 35.9 River Miles • Some houses near the bridge • No offshore or water's edge structures.	• River flows to the northwest • The river is single sinusoidal • The riverbanks have moderate to dense tree covers. • The width of the river ranges from 100 to 150 feet.	Good. Possible from near the bridge
36-37 Free River Reaches	R-1 FLT 13s-16 (Nov 99) Sheet 29 (Apr 91)	• M-40 skirts along the left (west) bank • Farm lands on the left bank mainly by the highway. • No offshore or water's edge structures.	• The river bends like a jug handle and flows to the east near the end of this stretch • The riverbanks have moderate tree covers. • The width of the river ranges from 100 to 150 feet.	Good Access possible from M-40 and nearby residential areas
37-38 Free River Reaches	R-1 FLT 13s-16 (Nov 99) R-1 FLT 12-15 (Nov 99) Sheets 29/30 (Apr 91)	• M-40 skirts along the left (west) bank. • Farm lands on the left bank mainly by the highway • No offshore or water's edge structures.	• The river turns to the east in this stretch. • The riverbanks have moderate tree covers. • The width of the river ranges from 150 to 200 feet in the main channel and 30 to 40 feet around islands	Good Access possible from nearby residential/farm areas

(See notes on page 7)

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
KALAMAZOO RIVER - SUMMARY OF BANK CONDITIONS KALAMAZOO TO LAKE ALLEGAN

River Mile[1]	Air Photo Number[2]	Structures and Features	Bank Conditions	Access[3]
38-39 Entering City of Allegan	R-1 FLT 12-15 (Nov 99) Sheet 30 (Apr 91)	• Residential developments on the right (east) bank, a few near the waterfront. Left bank largely undeveloped. • No offshore or water's edge structures. • Allegan City line at 38.6 River Miles.	• At the end of this stretch the river turns in a northerly direction • The riverbanks have moderate tree covers with some exposed areas • The width of the river ranges from 100 to 300 feet.	Good Access possible from nearby residential areas.
39-40 Allegan City Impoundment	R-1 FLT 12-15 (Nov 99) R-1 FLT 12-13 (Nov 99) Sheet 30 (Apr 91)	• Residential developments on parts of both banks with some undeveloped areas. • No offshore or water's edge structures.	• The river flows to the north into Allegan City Impoundment and forms several islands at the mouth. • The river is single sinusoidal. • The riverbanks have moderate to dense tree covers. • The width of the river ranges from 200 feet in the river to 1700 feet in the lake.	Good. Access possible from nearby residential areas
40-41 Allegan	R-1 FLT 12-13 (Nov 99) R-1 FLT 14-20 (Nov 99) Sheets 30/31 (Apr 91)	• Three roadway bridges cross the river in this stretch: M-89 bridge at 40.16 River Miles, 2nd Street bridge at 40.30 River Miles, and the Kent Street bridge at 40.45 River Miles (in the inlet that cuts into the left bank). These bridges range from 160 to 270 feet in length, and the channelized river beneath ranges from 150 to 250 feet in width. • Overhead cables cross the river along the M-89 bridge. • Allegan City Dam is located at 40 45 River Miles • One boat launch is located on the right (east) bank • Major residential and industrial developments occupy both banks. • No other offshore or water's edge structures • Tannery Creek enters river on left (west); Rossman Creek enters river on right (east)	• The river flows to the north. • The river is single and very sinusoidal. • A parking lot and a roadway extends along the left bank between M-89 bridge and the 2nd Street bridge. The bank in this stretch appears to be bulkheaded, and sheetpiled. • The left bank between the 2nd Street bridge and the dam is also partially channelized likely using concrete or fill materials. • Total channelized portion on the left bank is approximately 1600 feet. • The remaining portions of the banks have dense tree cover. • The width of the river ranges from 150 feet in the river to 1400 feet in the lake.	Good/Limited. Access possible from near the dam or from adjacent residential/industrial areas. Limited access between M-89 bridge and the dam. Good elsewhere
41-42 Allegan	R-1 FLT 14-20 (Nov 99) Sheet 31 (Apr 91)	• A linear structure, possibly a pipeline, extends into the river at 41 9 River Miles from the left bank. • Residential and industrial developments occupy parts of both banks with the remaining areas undeveloped. • No offshore or water's edge structures.	• This stretch forms part of a loop, at the end of which the river flows to the northwest direction. • River banks have moderate to dense tree covers. • The width of the river ranges from 100 to 150 feet.	Good. From d/s of Allegan City Dam and nearby roadways.
42-43 City of Allegan	R-1 FLT 14-20 (Nov 99) R-1 FLT 11-8 (Nov 99) Sheets 31/32 (Apr 91)	• M-222 bridge is located at 42.20 River Miles, approximately 200 feet long, and the river below is 130 feet wide. • A bridge-like structure, possibly a walkway, is located at 42.40 River Miles • Overhead cables cross the river at 43 River Miles. • Residential and industrial developments on parts of both banks with the remaining areas undeveloped. • No offshore or water's edge structures	• The river flows to the northwest direction. • A mid-channel island forms near the end of this stretch. • River banks have moderate to dense tree covers. • The width of the river ranges from 100 to 350 feet.	Good. From nearby industrial areas, and the fairground
43-44 Lake Allegan Begins	R-1 FLT 11-8 (Nov 99) R-1 FLT 15-20 (Nov 99) Sheets 32/33 (Apr 91)	• The county fairground is located on the left (south) bank. • Allegan WWTP is located on the right (east) bank • City roads pass adjacent to the outer bend on the right bank • Residential, farm lands, and a gravel pits occupy parts of the right bank with the remaining being wooded areas. • No offshore or water's edge structures.	• In this stretch the river turns to the west and becomes Lake Allegan. • A number of islands (low to moderate vegetation) are at the mouth. • River banks have moderate to dense tree covers. • The width of the river ranges from 200 feet to greater than 1000 feet The channels between the islands are 100 feet wide or more	Good. From the fairground, Allegan WWTP or nearby roads
44-45 Lake Allegan	R-1 FLT 11-6 (Nov 99) Sheet 33 (Apr 91)	• Mostly residential developments on both banks. • A gravel pit is located on the left (east) bank. A shed appears to be located by the water's edge near the gravel pit • No offshore or water's edge structures.	• The lake is oriented in an eastwest general direction. • The lake is single sinusoidal. • Shorelines have moderate to dense tree covers • Appears shallow with some underwater islands • The lake width ranges from 400 feet to more than 1000 feet.	Good. From nearby residential areas and roadways

(See notes on page 7)

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
KALAMAZOO RIVER - SUMMARY OF BANK CONDITIONS KALAMAZOO TO LAKE ALLEGAN

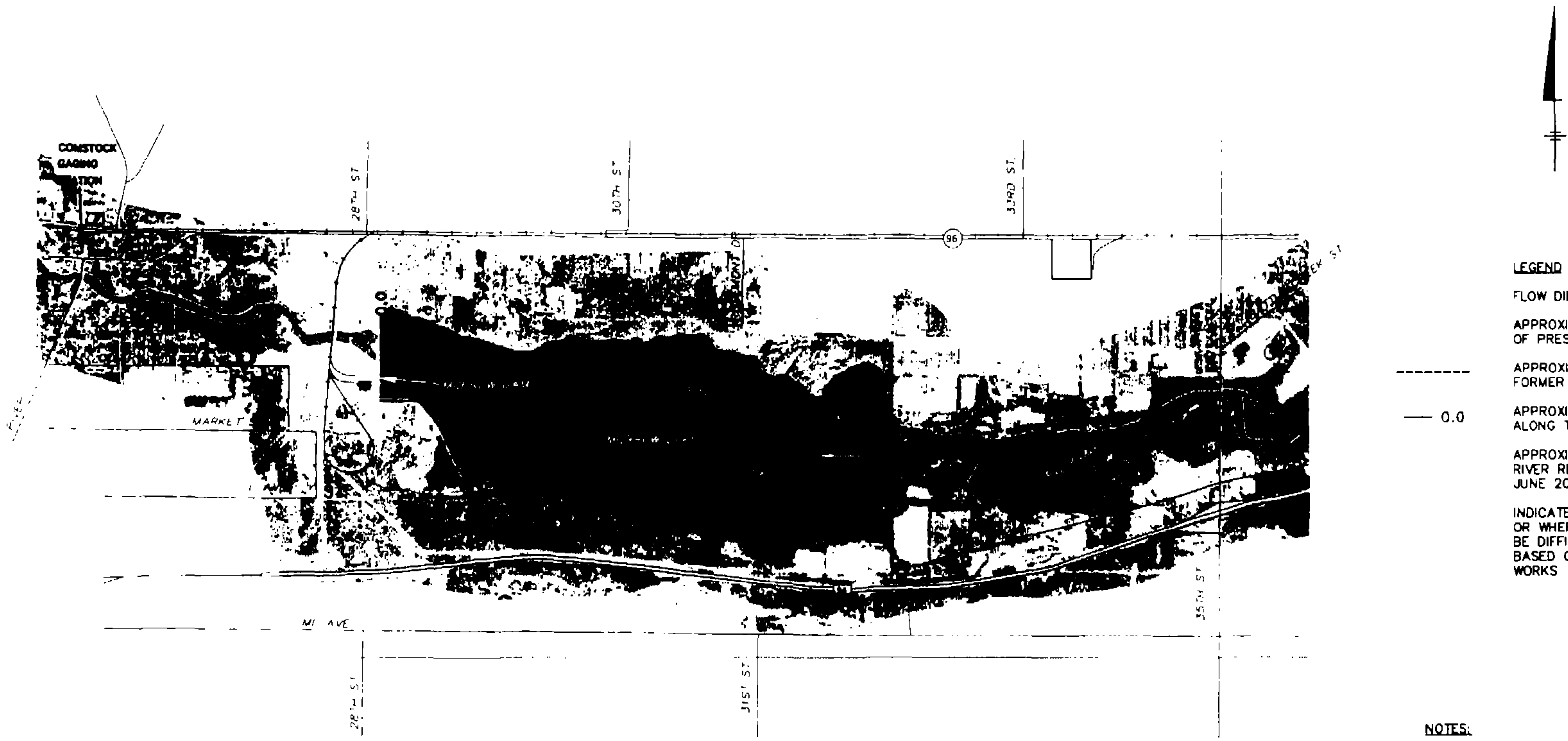
River Mile[1]	Air Photo Number[2]	Structures and Features	Bank Conditions	Access[3]
45-46 Lake Allegan	R-1 FLT 11-4 (Nov 99) R-1 FLT 12-8 (Nov 99) Sheet 34 (Apr 91)	• M-40/M-89 bridge crosses the lake at 45 75 River Miles The bridge is about 200 feet long and the river below is 190 feet wide. • Monroe Road runs along the left bank Parts of the road abuts the lake and is protected by ripraps (approximately 1000 feet). • About 9 boat launch/docks were identified on both banks. • Residential development occupy parts of both banks.	• The lake is oriented in an eastwest general direction. • Shorelines have low to moderate tree covers, but many of the bank areas have more recent tree growths. • The lake width ranges from 200 feet near the bridge to more than 2000	Good From Monroe Road or residential areas
46-47 Lake Allegan	R-1 FLT 12-8 (Nov 99) R-1 FLT 17-35 (Nov 99) Sheet 34 (Apr 91)	• M-40/M-89 runs along the right bank (east) and Monroe Road runs along the left (west) bank. • Several boat launch areas/docks were identified on both banks. • The banks characterize residential, wooded and/or recent growth areas Some of the houses are located at the waterfront	• The lake is oriented in an eastwest general direction • Shorelines have low to moderate tree covers, parts of the bank areas have more recent tree growths. • The lake width ranges from 400 feet to 900 feet.	Good. From M-40/M-89, Monroe Road or residential areas.
47-48 Lake Allegan	R-1 FLT 17-33 (Nov 99) R-1 FLT 14-12 (Nov 99) Sheet 35 (Apr 91)	• Monroe Road continues along the left (south) bank, and Allegan Dam Road runs along the right (north) bank. • 9 boat launch areas/docks were identified on both banks • The banks characterize residential and wooded areas	• The lake is oriented in an eastwest general direction • Shorelines have low to moderate tree covers. • The lake further widens in this area to more than 2500 feet.	Good From residential areas and nearby roadways
48-49 Lake Allegan	R-1 FLT 14-10 (Nov 99) R-2 FLT 15-10 (Nov 99) Sheets 35/36 (Apr 91)	• Monroe Road skirts along the left (south) bank, and Allegan Dam Road runs along the right (north) bank. • 7 boat launch areas/docks were identified on both banks. • The banks characterize residential and wooded areas	• The lake is oriented in an eastwest general direction • Shorelines have low to moderate density tree covers. • The lake is between 1800 and 3000 feet wide	Good From residential areas and nearby roadways
49-51 Lake Allegan Ends	R-1 FLT 14-8 (Nov 99) R-2 FLT 15-8 (Nov 99) R-2 FLT 14-6 (Nov 99) R-1 FLT 13n-28 (Nov 99) Sheets 36/37 (Apr 91)	• Roadways skirt along the entire perimeter Allegan Dam Road skirts the waterfront in the northwest shoreline About 1100 feet of the lakeside of the road is riprapped. • Several waterfront structures including boat launch areas, houses, etc. were identified on the banks. • Lake Allegan Dam is located at the northwest end of the lake.	• The lake is oriented in an eastwest general direction. • Allegan State Game Area skirts the southwestern and the western edges of Lake Allegan • Shorelines have moderate tree covers. • The lake is between 1800 and 3000 feet wide.	Good From surrounding roadways, the dam, and residential areas

Notes:
1 The "Zero" river mile starts at Morrow Dam and increases in the downstream direction.
2 Primarily two sets of air photos were reviewed These include the November 17, 1999 air photos taken between Kalamazoo and Lake Allegan, and the April 1991 air photos taken in the same region.
3 Access to the river for water-based construction is rated as good or limited as follows:
- Access is rated as good when existing roadways are located within 1/2 mile of the river banks and suitable land is available for constructing access/sediment handling areas, or if the nearest access point is located within 2 River Miles
- Access is rated as limited when the nearest roadway is located greater than 1/2 mile distance, or suitable land is not available/limited for constructing an access point, or if two low bridge or dam structures are located within one half mile of the River

4 The banks are described as left or right bank facing downstream at a given location.
5 In addition, still pictures of the river banks at selected locations (June/July 1998 and May 2000) and aerial photographs near the Portage Creek (December 1999) were also reviewed
6 u/s = upstream, d/s = downstream

Figures

BLASLAND, BOUCK & LEE, INC.
engineers & scientists



LEGEND

FLOW DIRECTION

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE BOUNDARY OF FORMER IMPOUNDMENT

0.0 APPROXIMATE RIVER MILES ALONG THE MAIN CHANNEL

APPROXIMATE LOCATION OF RIVER REACHES VISITED IN JUNE 2000

INDICATES LIMITED ACCESS, OR WHERE ACCESS WOULD BE DIFFICULT FOR WATER BASED CONSTRUCTION WORKS

NOTES:

1. PLANIMETRIC MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEMS.
2. AERIAL IMAGE DERIVED FROM ORTHOPHOTOGRAPHIC DATA BY AIR LAND SURVEYS, INC., FLOWN 4/24/99

0 2400' 4800'

SCALE

KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

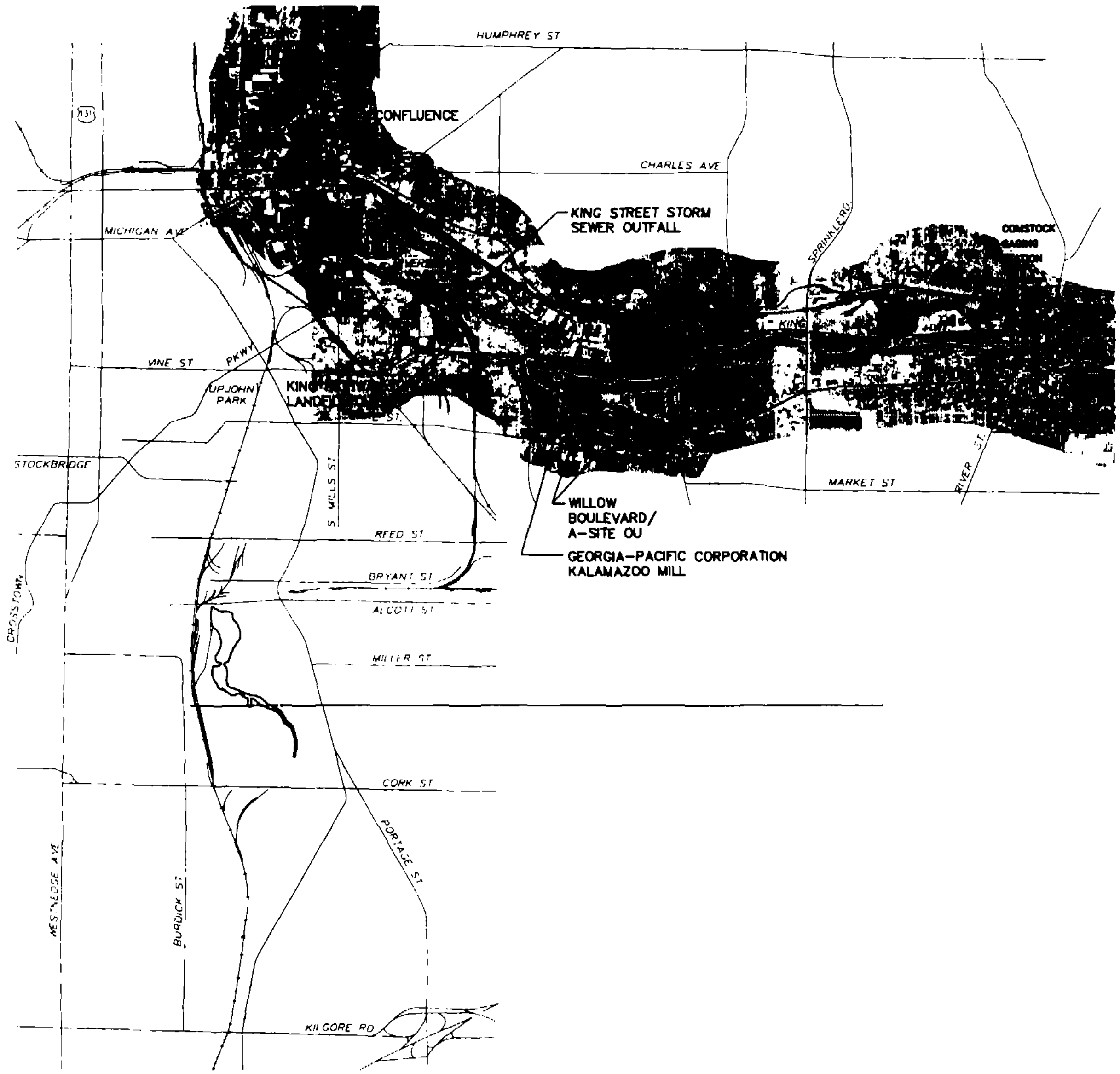
FEASIBILITY STUDY REPORT

MORROW LAKE

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 1

10/24/00 SYR-54-RLP DCC SDL



LEGEND

FLOW DIRECTION

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE BOUNDARY OF FORMER IMPOUNDMENT

1.0 APPROXIMATE RIVER MILES ALONG THE MAIN CHANNEL

APPROXIMATE LOCATION OF RIVER REACHES VISITED IN JUNE 2000

INDICATES LIMITED ACCESS, OR WHERE ACCESS WOULD BE DIFFICULT FOR WATER BASED CONSTRUCTION WORKS

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0 2400' 4800'

SCALE

DRAFT

FOR STATE AND FEDERAL REVIEW

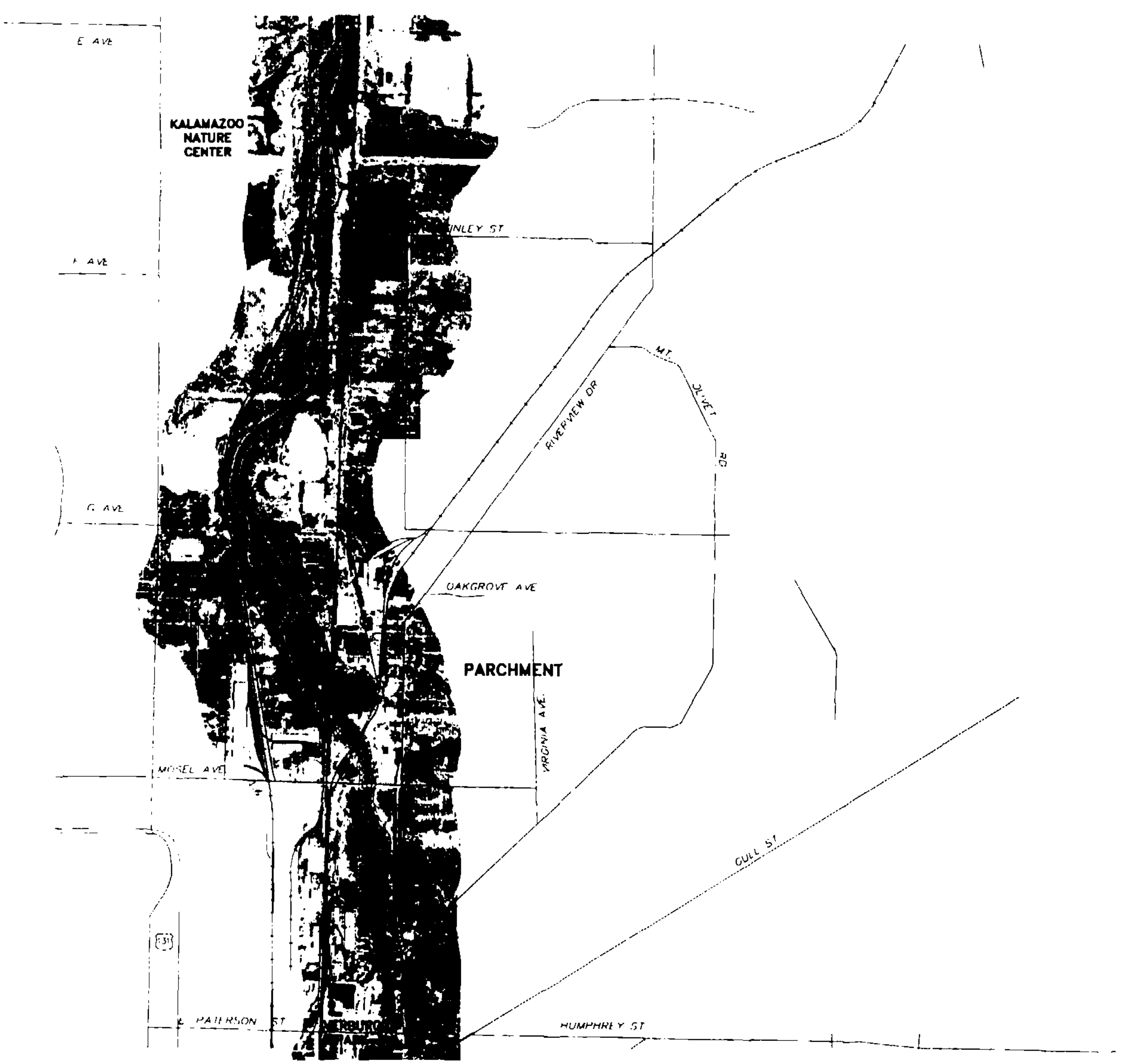
KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT

PORTAGE CREEK/KALAMAZOO RIVER CONFLUENCE

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 2



LEGEND

FLOW DIRECTION

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE BOUNDARY OF FORMER IMPOUNDMENT

— 7.0 APPROXIMATE RIVER MILES ALONG THE MAIN CHANNEL

APPROXIMATE LOCATION OF RIVER REACHES VISITED IN JUNE 2000

INDICATES LIMITED ACCESS, OR WHERE ACCESS WOULD BE DIFFICULT FOR WATER BASED CONSTRUCTION WORKS

NOTES:

1. PLANIMETRIC MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEMS.
2. AERIAL IMAGE DERIVED FROM ORTHOPHOTOGRAPHIC DATA BY AIR LAND SURVEYS, INC., FLOWN 4/24/99.

0 2400' 4800'

SCALE

DRAFT

FOR STATE AND FEDERAL REVIEW

KALAMAZOO RIVER STUDY GROUP

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT

KALAMAZOO RIVER DOWNSTREAM OF THE PORTAGE CREEK CONFLUENCE

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FIGURE 3

LEGEND

FLOW DIRECTION

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE BOUNDARY OF FORMER IMPOUNDMENT

13.0 APPROXIMATE RIVER MILES ALONG THE MAIN CHANNEL

APPROXIMATE LOCATION OF RIVER REACHES VISITED IN JUNE 2000

INDICATES LIMITED ACCESS. OR WHERE ACCESS WOULD BE DIFFICULT FOR WATER BASED CONSTRUCTION WORKS

NOTES:

1. PLANIMETRIC MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEMS.
2. AERIAL IMAGE DERIVED FROM ORTHOPHOTOGRAPHIC DATA BY AIR LAND SURVEYS, INC., FLOWN 4/24/99.

0 2400' 4800'

SCALE

DRAFT
FOR STATE AND FEDERAL REVIEW

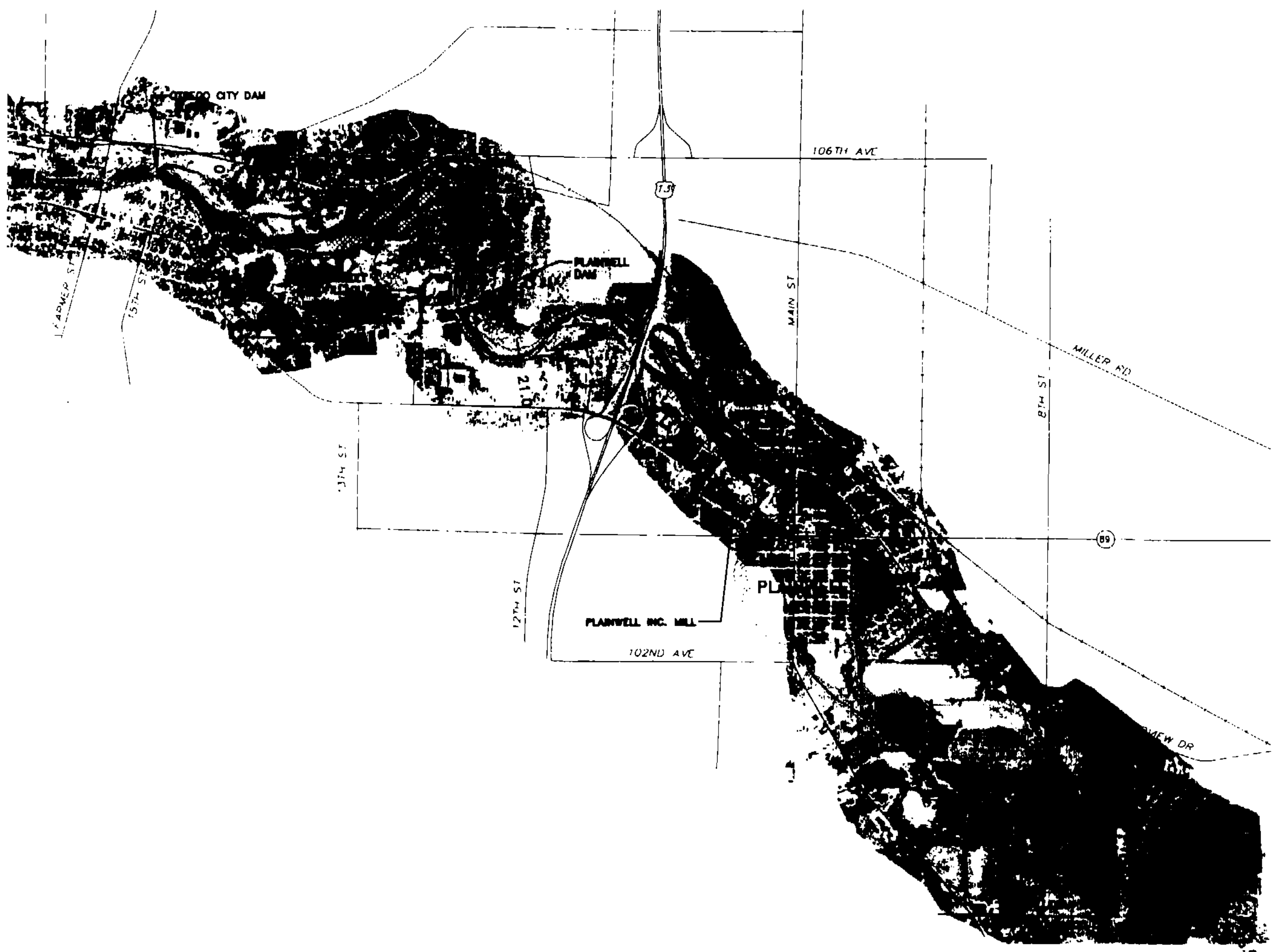
KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT

KALAMAZOO RIVER UPSTREAM OF PLAINWELL

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 4



LEGEND

FLOW DIRECTION

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE BOUNDARY OF FORMER IMPOUNDMENT

22.0 APPROXIMATE RIVER MILES ALONG THE MAIN CHANNEL

APPROXIMATE LOCATION OF RIVER REACHES VISITED IN JUNE 2000

INDICATES LIMITED ACCESS, OR WHERE ACCESS WOULD BE DIFFICULT FOR WATER BASED CONSTRUCTION WORKS

NOTES:

1. PLANIMETRIC MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEMS.
2. AERIAL IMAGE DERIVED FROM ORTHOPHOTOGRAPHIC DATA BY AIR LAND SURVEYS, INC., FLOWN 4/24/99.

0 2400' 4800'

SCALE

DRAFT

FOR STATE AND FEDERAL REVIEW

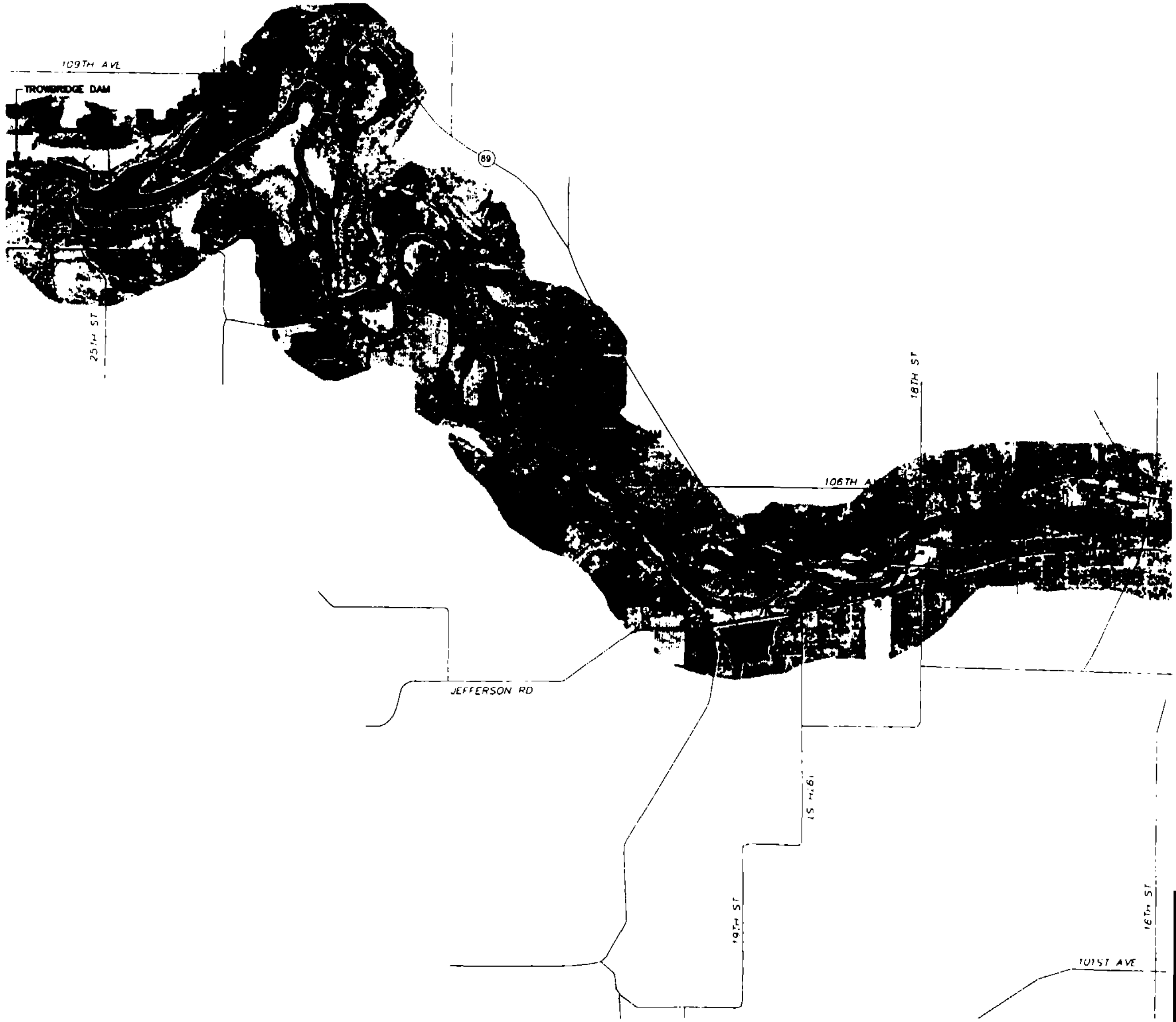
KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT

FORMER PLAINWELL AND OTSEGO CITY IMPOUNDMENTS

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 5



LEGEND

FLOW DIRECTION

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE BOUNDARY OF FORMER IMPOUNDMENT

24.0 APPROXIMATE RIVER MILES ALONG THE MAIN CHANNEL

APPROXIMATE LOCATION OF RIVER REACHES VISITED IN JUNE 2000

INDICATES LIMITED ACCESS, OR WHERE ACCESS WOULD BE DIFFICULT FOR WATER BASED CONSTRUCTION WORKS

NOTES:

1. PLANIMETRIC MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEMS.
2. *AERIAL IMAGE DERIVED FROM ORTHOPHOTOGRAPHIC* DATA BY AIR LAND SURVEYS, INC., FLOWN 4/24/99.

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SCALE

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FORMER OTSEGO AND FORMER TROWBRIDGE IMPOUNDMENTS

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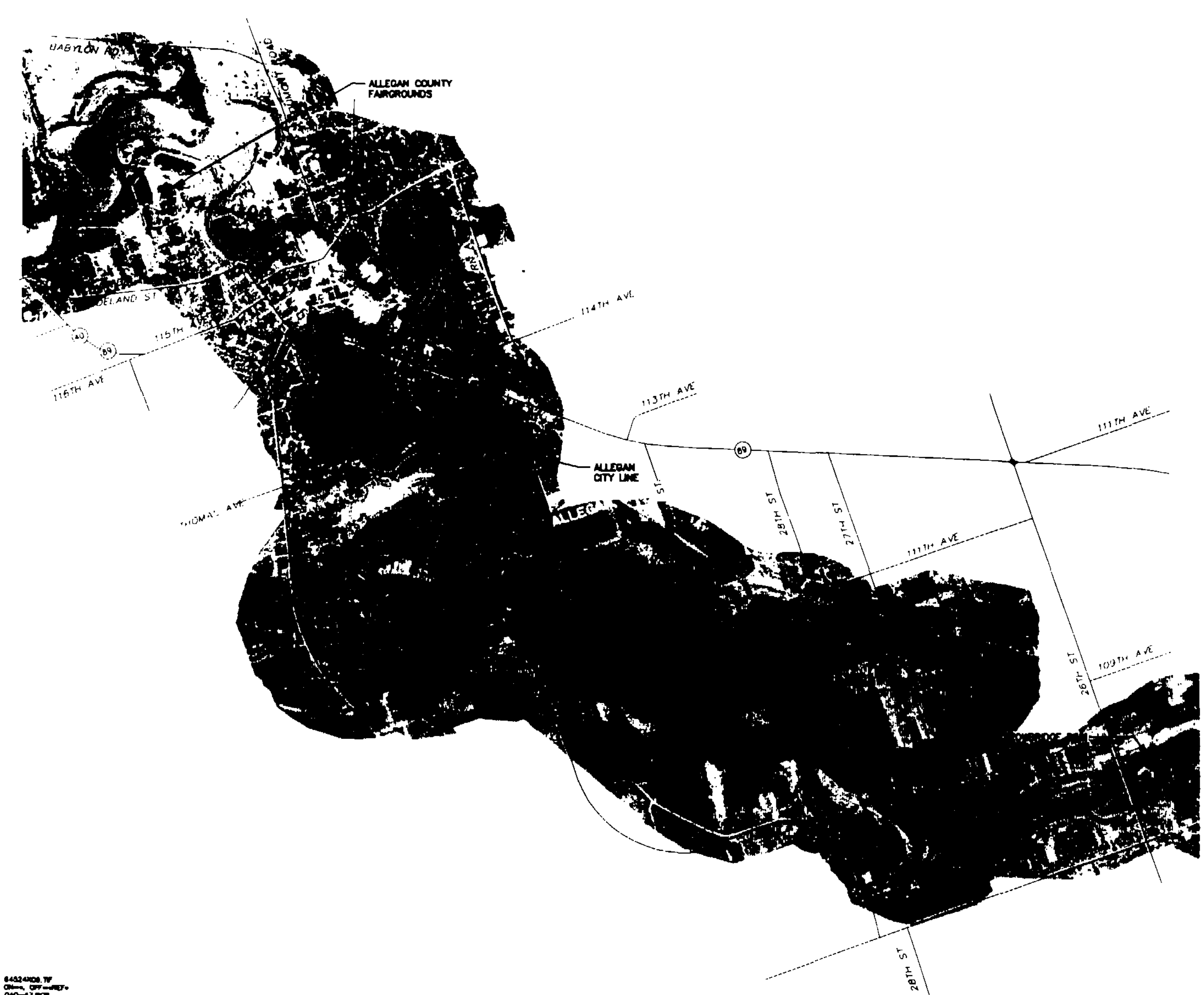
FIGURE **6**



LEGEND

FLOW DIRECTION

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE BOUNDARY OF FORMER IMPOUNDMENT

35.0 APPROXIMATE RIVER MILES ALONG THE MAIN CHANNEL

APPROXIMATE LOCATION OF RIVER REACHES VISITED IN JUNE 2000

INDICATES LIMITED ACCESS, OR WHERE ACCESS WOULD BE DIFFICULT FOR WATER BASED CONSTRUCTION WORKS

NOTES:

1. PLANIMETRIC MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEMS.
2. AERIAL IMAGE DERIVED FROM ORTHOPHOTOGRAPHIC DATA BY AIR LAND SURVEYS, INC., FLOWN 4/24/99.

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KALAMAZOO RIVER FROM TROWBRIDGE DAM TO LAKE ALLEGAN

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FIGURE 7

LEGEND

FLOW DIRECTION

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE BOUNDARY OF FORMER IMPOUNDMENT

45.0 APPROXIMATE RIVER MILES ALONG THE MAIN CHANNEL

APPROXIMATE LOCATION OF RIVER REACHES VISITED IN JUNE 2000

INDICATES LIMITED ACCESS, OR WHERE ACCESS WOULD BE DIFFICULT FOR WATER BASED CONSTRUCTION WORKS

NOTES:

1. PLANIMETRIC MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEMS.
2. AERIAL IMAGE DERIVED FROM ORTHOPHOTOGRAPHIC DATA BY AIR LAND SURVEYS, INC., FLOWN 4/24/99.

0 2400' 4800'

SCALE

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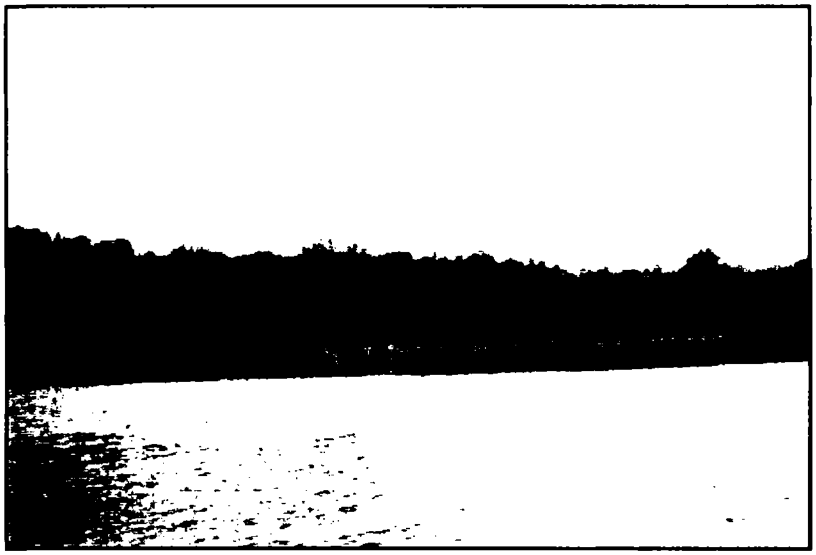
LAKE ALLEGAN

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 8

10/24/00



MARSH VEGETATION BANK TYPE 1
Root mat at water level, minimal erosion above water line.

MARSH VEGETATION BANK TYPE 2
Overhanging root mat 6" to 2' above water line, bank is eroded/recessed near vertical face.

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MARSH VEGETATION BANK TYPES 1 AND 2

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FIGURE 9

08/00 SYR-D54-DJH LBR
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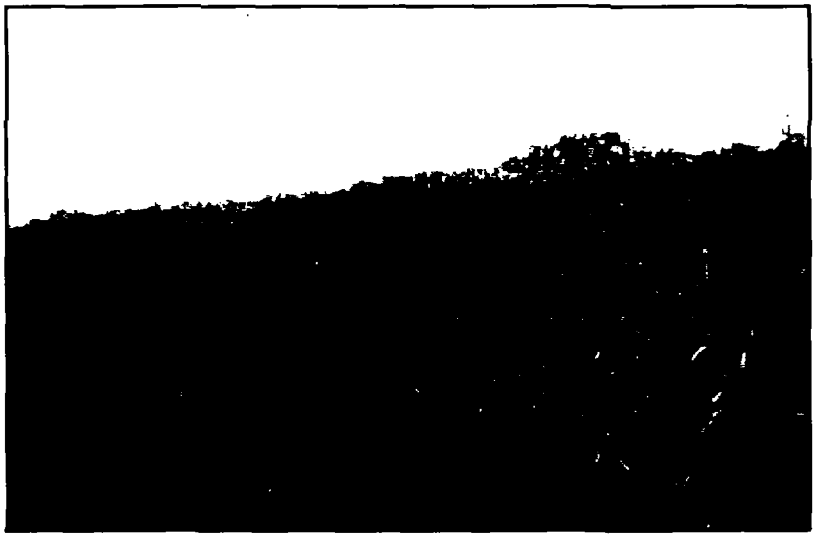

MARSH VEGETATION BANK TYPE 3
Steep (45°+) exposed face 1' to 3' high above sloping (3H:1V to 10H:1V) spalled material typically 6" to 12" above water line. Root mat is at top of exposed face with little overhang.

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MARSH VEGETATION BANK TYPE 3

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64524640/64524n10 cdr

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FIGURE 10

TREES/SHRUBS BANK TYPE 1
Trees/shrubs rootmat, grass and leaf mold nearly to waterline. Slopes usually flatter than 4H:1V.

TREES/SHRUBS BANK TYPE 2
Tipping trees/dead stumps due to erosion of soil from below the tree roots. Slopes can be steeper than 4H:1V locally.

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TREES/SHRUBS BANK TYPES 1 AND 2

08/00 SYR-D54-DJH LBR
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FIGURE 11

TREES/SHRUBS BANK TYPE 3
Near vertical clay (1' to 3' thick) above exposed sand. Sand usually slopes down to water at 2H:1V or flatter. Steeper sand can occur on outside bank of curve where more active erosion is occurring.

TREES/SHRUBS BANK TYPE 4
Steep natural sand slopes, partially bare, no sediments on bank. No additional protection required.

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TREES/SHRUBS BANK TYPES 3 AND 4

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 12

08/00 SYR-D54-DJH LBR
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CHANNELIZED RIVER BANK
Riprap protection.

CHANNELIZED RIVER BANK
Concrete wall that joins a sheetpile wall further upstream.

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CHANNELIZED RIVER BANKS

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FIGURE 13

08/00 SYR-D54-DJH LBR
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Appendix B

BLASLAND, BOUCK & LEE, INC.
engineers & scientists

Design Concepts and Preliminary Cost Estimates for Alternative 3

Appendix B – Design Concepts and Preliminary Cost Estimates For Alternative 3

1.0 Introduction

This appendix presents feasibility-level design concepts and construction cost estimates for the proposed bank stabilization at the former Plainwell, Otsego, and Trowbridge impoundments, the primary component of Alternative 3, as presented in the Feasibility Study (FS) Report. Bank stabilization measures have been proposed to mitigate the ongoing erosion and sloughing of the banks into the river and reduce the potential for downstream transport of polychlorinated biphenyls (PCB). Several bank stabilization measures specific to existing Site conditions (discussed in Appendix A to the FS Report) have been proposed to meet the stated goals. This alternative is intended to address unstable bank slopes and river meander within the Michigan Department of Natural Resources (MDNR)-owned former impoundments using several technologies, as appropriate, considering such factors as vegetative cover, bank slope, river velocity, thickness of PCB-containing sediments, and thickness of exposed underlying soils. The proposed approach and associated preliminary cost estimates are further discussed in the subsections below.

2.0 Proposed Bank Stabilization Methods

The following paragraphs characterize the riverbanks in the former impoundments, establish the types of bank systems that are currently in place, and propose bank stabilization methods suitable for each bank type for long-term physical stability, thus preventing further migration of PCB into the river. Note that this is a feasibility-level characterization effort; more detailed riverbank characterization will be needed prior to developing detailed design information.

2.1 Current Bank Conditions

In June of 1998, a small boat was used to float substantial areas of the former Plainwell, Otsego, and Trowbridge impoundments. The former Plainwell Impoundment was again visited in June of 2000. In addition, aerial photographs of the river between Kalamazoo and Lake Allegan, taken in April 1991 (Lockwood, 1991), April 1999 (Air Land Surveys, Inc., 2000), and November/December 1999 (Lockwood, 1999), were used to evaluate the banks.

Based on field observations, still photographs, aerial photography, and topographic map information, two general categories of bank types were identified within the former impoundments: Marsh Vegetation Bank Type and Tree/Shrub Vegetation Bank Type. Seven typical bank types were then identified within these two general categories: three marsh vegetation bank types and four tree/shrub vegetation bank types. This characterization of the riverbanks (i.e., bank types) is based on such factors as vegetation cover and type, geometry of the banks (i.e., bank slopes, erosion faces, slumping, etc.), bank material (i.e., if the bank is formed of native sand and gravel, or sediments, or both, etc.), and relative location of water level (defined as the water surface elevation at average flow conditions) in the banks. The banks were grouped in this manner to identify common features and to provide a basis for developing bank stabilization measures that are appropriate for each bank type. In addition to the factors identified above, other factors such as river velocity, the PCB concentrations in the bank soil, thickness of PCB-containing soils, and thickness of sediments at the bank toe, etc., were also considered in developing the proposed bank stabilization concepts.

Within the former MDNR-owned impoundments, seven typical bank types were identified within two general categories: three marsh vegetation bank types and four tree/shrub vegetation bank types. These are discussed below. Photographs of the various bank types are shown in Figures 9 through 12 of Appendix A to the FS Report. Note that this classification is based on observations made during the site visits in 1998 and in 2000. A more detailed delineation of the banks would be necessary prior to finalizing the bank stabilization design concepts discussed here.

The three marsh vegetation bank types are described below:

> **Marsh Vegetation Bank Type 1:** Root mat is at water level, and there is minimal erosion above the water line.
>
> **Marsh Vegetation Bank Type 2:** Overhanging root mat is 6 inches to 2 feet above the water line, and the bank is eroded/recessed to a near vertical face.
>
> **Marsh Vegetation Bank Type 3:** Steep (45 degrees or steeper) exposed face 1 foot to 3 feet high above sloping (3 horizontal: 1 vertical [3H:1V] to 10H:1V) spalled material, which is typically 6 inches to 1 foot above the waterline. The root mat is at the top of the exposed face with little overhang.

The four tree/shrub vegetation bank types are described below:

> **Tree/Shrub Vegetation Bank Type 1:** Tree/shrub root mat, grass and leaf mold nearly to waterline. Slope usually flatter than 4H:1V.
>
> **Tree/Shrub Vegetation Bank Type 2:** Tipping trees/dead stumps due to erosion of soil from below the tree roots. Slopes can locally be steeper than 4H:1V.

Tree/Shrub Vegetation Bank Type 3: Near vertical clay (1 to 3 feet thick) above exposed sand. Sand usually slopes down to water at 2H:1V or flatter. Steeper sand can occur on outside bank curve where more active erosion is occurring.

Tree/Shrub Vegetation Bank Type 4: Steep sand slopes that are partially bare.

A summary of bank lengths for each bank type encountered at each of these impoundments is provided in the table below. Refer to Appendix A of the FS Report for a more detailed description of various bank types encountered along the remaining river reaches between Morrow Dam and Lake Allegan Dam.

Summary of Bank Type Lengths

Bank Type	Former Impoundment Bank Lengths (feet)			
	Plainwell	**Otsego**	**Trowbridge**	**Total**
Marsh 1	7,600	8,700	1,100	17,400
Marsh 2	3,400	6,700	9,800	19,900
Marsh 3	0	0	22,700	22,700
Tree/Shrubs 1	4,700	2,400	0	7,100
Tree/Shrubs 2	2,600	4,300	9,900	16,800
Tree/Shrubs 3	0	0	11,900	11,900
Tree/Shrubs 4	0	0	8,000	8,000
Totals	**18,300**	**22,100**	**63,400**	**104,000**

2.2 Delineation of Former Impoundment Limits

A sediment investigation was performed between November 1993 and February 1994 in the former Plainwell, Otsego, and Trowbridge impoundments (presented in *Draft Technical Memorandum 12*, Blasland, Bouck & Lee, Inc. [BBL], 2000a). The investigation included the establishment of 6 transects within each of the former Plainwell and Otsego impoundments, and 9 transects within the former Trowbridge Impoundment. Based on the 1993/1994 sediment investigation and field observation, the outward lateral extent of each of the former impoundments was established based on one or more of the following criteria: 1) where sediment/soil PCB concentrations below 1 ppm (mg/kg) were first encountered, 2) where native soil can be identified, and 3) where a physical feature such as a steep bank will effectively limit the impoundment. Finally, the results from the field observation and laboratory PCB data were compared with the historical headwater levels at the former impoundments prior to the lowering of the water levels by MDNR in the 1970s.

It appears that the former impoundment limits lie approximately within the former headwater elevations. Therefore, the extent of the former impoundments were delineated based on both the 1993/1994 sediment investigation and former headwater elevations at these impoundments. This is consistent with the impoundment limits delineated in the Remedial Investigation (RI) Report (BBL, 2000b).

2.3 Design Concepts

Figures 1 through 3 show tentative alignments of the proposed riverbank stabilization work in the former Plainwell, Otsego, and Trowbridge impoundments. As discussed above, the extent of stabilization work is based on the historical impoundment elevations prior to lowering the water levels to the current sill levels and the findings of the 1993/1994 sediment investigation.

Presently, nearly all of the bank erosion occurs due to disintegration of the soil matrix caused by weathering and undercutting by the river. Therefore, protection against weathering and scour are the primary design objectives of the proposed bank stabilization program. Bank stabilization methods would generally consist of installation of riprap (locally-obtained material) or other reinforcement systems (reno mattress, articulated concrete block, sand- and gravel-filled cellular confinement web, etc.) above or below the water line. Covering the surface of the fine-grained sediments with locally-obtained riprap materials will protect the exposed sediment surfaces from further weathering, while restoring a bank surface similar to the stable and natural conditions that existed before the dams were built and water was impounded. Typical bank stabilization measures specific to each bank type are shown in Figures 4 through 11.

It is expected that 4- to 8-inch diameter riprap will be suitable for use in most areas of the banks along the former impoundments. In low velocity areas, sand to gravel-sized materials may be sufficient. Larger boulder or crushed concrete (commonly used on Michigan Department of Transportation and MDNR projects) may be needed in higher velocity areas, particularly near the dams and localized areas on meander bends. Other armoring techniques that may be used below the water line include Reno mattresses or other confinement systems infilled with sand and gravel, and articulated concrete block mats. The use of a geotextile below these systems is expected to be beneficial in areas where fine sediments are present below the water surface.

In reaches of the river where there is significant fine-grained sediment thickness (i.e., greater than 2 feet) at the toe of the bank and extending into the bottom of the river, it is anticipated that some additional protection will be required on the river bottom to protect against scour during major flood events. The illustrations of the various erosion control measures (Figures 4 through 11) show a "launching apron" of riprap, which is designed to control scour of the sediments from below the bank armoring system. As soft sediments are scoured from below this apron area, the apron materials will collapse, but the stability of the adjacent bank slope will be preserved. The scour protection measure is expected to mimic the natural self-armoring process of the river system that would have occurred if the dams had not been built. This natural process would have left larger granular material in place as the finer sands and gravels in the matrix were eroded, thereby eventually creating a natural riprap.

Steep banks with fine-grained sediments that extend more than 1 to 2 feet above the normal water surface (at average flow conditions) and exhibit unstable conditions may need additional stabilization measures, as shown in Figures 4 through 11. These measures range from biotechnical erosion control techniques using bio-logs and live willow stakes to traditional gabion baskets. The primary purpose of these measures is to provide adequate structural support for the bank, while protecting it from scour during major erosion events.

It is anticipated that an access road will be required along the top of the banks in the areas where riverbank stabilization will take place to provide access, particularly in the soft sediments within the exposed floodplain, and to bring in material and equipment. The access roads will be constructed of local sands and gravels. Note that clearing and grubbing will be needed to construct the access road and to perform the bank stabilization work. The access road will be left in place after the project.

The Kalamazoo River traverses a large outwash plain with natural soils that are predominantly sands, gravels, and cobbles. The numerous local gravel pits that are mined in the area are the proposed source of the materials that will be used for constructing the bank stabilization components and to construct the access roads (note that certain specific sizes of necessary materials may not be available locally in sufficient quantities). Cobbles from these gravel pits are expected to be used for riprap which will extend from the top of the bank to below the water line. The use of natural sands and gravels for the access road and the cobble riprap along the bank is expected to provide a stable riverbank system that is similar to the original pre-impoundment banks of the river.

3.0 Preliminary Cost Estimates

This section provides a description of the tasks associated with the proposed bank stabilization work, presents the preliminary cost tables to complete the proposed works, and lists the assumptions made to arrive at the preliminary costs.

3.1 Riverbank Stabilization

The anticipated alignments of the proposed bank stabilization work within the former Plainwell, Otsego, and Trowbridge impoundments are shown on Figures 1 through 3. The conceptual sections of the proposed stabilization techniques for various bank types are illustrated in Figures 4 through 11.

The stabilization of the riverbanks will involve the following:

- Clearing (i.e., vegetation and debris) and grubbing for access road construction and bank stabilization works.

- Construction of access roads along the affected areas as indicated in Figures 1 through 3. The access roads will be 16 feet wide with additional ingress and egress points, and turning areas as needed. The access roads will be constructed of a 12 to 18-inch layer of locally available sand and gravel material. Geotextile and/or geogrid will be used as needed to reinforce the road over soft soils. The roadbeds will be left in place at the conclusion of the riverbank stabilization work.

- Riverbank stabilization will include several of the proposed bank stabilization methods illustrated in Figures 4 through 11, and will involve several construction materials. However, for the purpose of this cost estimate, it is assumed that the stabilization work will generally consist of the installation of riprap (cobbles, sand, and gravel) above and below the current water line. Native sand and gravel backfill will be placed in sloughed or eroded areas. Finally, topsoil will be placed on the disturbed areas, and the restored areas revegetated.

- An erosion control fence will be placed where necessary along the length of the affected riverbanks.

General cost items to perform the above tasks would include mobilization/demobilization and general conditions (i.e., project administration, miscellaneous costs, etc.). It is also expected that stabilization activities will be performed by means of a barge where river depths allow and where access from shore is not suitable.

Tables 1 through 3 present estimated material quantities and costs for the proposed bank stabilization work at the former Plainwell, Otsego, and Trowbridge impoundments. Table 4 summarizes the costs for all three impoundments.

3.2 Bank Restoration and Environmental Enhancements

Bank stabilization measures that include hard armor elements will generally be covered with soil and revegetated with native emergent herbaceous species at the water line, and herbaceous plants and woody shrubs above the waterline. The relatively low river velocities during normal flows along much of the impoundment reaches should allow for vegetated soils to remain in place in most areas. Vegetation at and above the water line should slow water velocities immediately adjacent to the bank and promote additional sedimentation along the shoreline.

The plant species will be selected specifically to maximize habitat quality for native wildlife species, while not interfering with the long-term integrity of the bank stabilization measures. Revegetation measures will include seeding, live staking, plant plugs, and potted/balled trees. Tree species will be selected to include both fast-growing colonizing species such as willows and aspen, and hardwood trees that normally appear in later successions such as oaks, hickories, and walnuts. Providing a diverse tree population along the river front is expected to accelerate the recovery of the riverbank area to a mature forested system where possible.

Revegetation along the riverbanks in the impoundments should create diverse ecotonal or "edge" habitat where little exists today, and provide an ecologically and aesthetically pleasing finish to the areas disrupted during construction. Additional habitat will be created by placing large wood debris and brush piles along the access roads and riverbanks to reestablish suitable wildlife habitat for songbirds and small mammals.

In the river, a series of in-river and bank structures will be placed at appropriate locations to provide shade and shelter for fish. Figures 12 through 14 show typical structures that will be employed that have been demonstrated to be effective in other rivers and streams classified as B5 or C5 (see Section 3 of the RI Report ([BBL, 2000b] for definitions), or anastomosed using Rosgen's classification system (Rosgen, 1996 and U.S. Department of Agriculture [USDA], 1998). The incorporation of these enhancements, including large wood debris in the river and on the riverbanks as well as revegetation of the shoreline, should restore the river system in areas where good habitat currently exists and enhance the river ecosystem in areas where habitat is still recovering after the rapid lowering of the impoundment water levels.

3.3 General Assumptions

The costs for bank stabilization for each of the former impoundments are presented in Tables 1 through 3. Table 4 summarizes the total cost of bank stabilization in all three impoundments.

The costs include the supply and installation of all materials. A 20% contingency amount and a 15% engineering fees amount have been included in the cost estimates. All costs are reported in 2000 dollars with no provision for escalation. Present worth is estimated based on a 7% beginning-of-year discount rate, adjusted for the effect of inflation. The costs are expected to be accurate to within -30%/+50% of the average contractor bid price if the work was put out for competitive bid under current economic conditions. This cost estimate should not be used for any purpose other than assessing the feasibility of the project and establishing preliminary budgets.

Specific assumptions made to arrive at individual tasks are presented below:

- Mobilization/demobilization (labor, material, equipment, etc.) is based on a 3% of the total cost before engineering fees and contingency allowance.

- An allowance is made for general conditions (i.e., contractor overhead, project administration, and miscellaneous costs including health and safety and temporary construction trailer facility expenses). This is based on a 1.5% of the total cost before engineering fees and contingency allowance.

- Clearing refers to clearing of vegetation and debris prior to riverbank stabilization. It is assumed that the entire length of the affected riverbanks will require clearing.

- The length of the access road is estimated as follows: Length of Access Road = Length of Riverbank (L) x 1.2 (factor used to compensate for increased length due to sinuosity) x 1.1 (factor used to account for local problem areas). The costs were then estimated based on estimated road surface area assuming a 16-foot wide roadway. It was assumed that the entire road surface will be restored (i.e., revegetated) at the conclusion of the proposed bank stabilization work.

- Riverbank slope lengths were determined using field transects. The length of the launching apron was determined as 2 x D (where D = the depth of sediment at the toe). The slope area between two field transects was determined by multiplying the average slope length for the transects plus the length of the launching apron by the distance between the transects. The total bank slope area requiring stabilization was then determined by summation. The estimated bank surface area was then corrected as follows: Surface Area for bank stabilization = bank slope area determined from transects x 1.1 (factor used to account for local problem areas).

- Backfill volume for riverbank stabilization was determined by assuming that approximately 40% of the bank will require backfill to address localized vertical sloughing and erosion. A 10 foot by 3 foot (typical sloughing height) or 15 square feet backfill wedge was assumed. Finally, the backfill volume was determined as follows: Backfill volume = Length of Riverbank (L) x Area of Backfill Wedge x 0.4 (length factor assumed needing backfill) x 1.1 (factor used to account for local problem areas).

- It was assumed that 50% of the surface area of the stabilized bank would be revegetated (i.e., the area above water line). This area was estimated as follows: Bank area requiring revegetation = 0.50 (submergence factor) x bank area determined from transects x 1.1 (factor used to account for local problem areas).

- Length of erosion control measures were determined as follows: Length requiring erosion control = Length of Riverbank (L) x 1.2 (factor used to compensate for increased length due to sinuosity) x 1.1 (factor used to account for local problem areas).

- A lump sum cost was assumed for the barge operation. Costs associated with a barge/work platform include an excavator mounted on a stationary barge and transport barge for ferrying materials and personnel to the stationary barge.

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Tables

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
BANK STABILIZATION - PLAINWELL IMPOUNDMENT

Item No.	Description		Quantity	Unit	Unit Cost (rounded)	Item Cost (rounded)
1	Mobilization/demobilization		1	lump sum	$166,000	$166,000
2	General conditions		1	lump sum	$83,000	$83,000
3	Clearing		20,000	linear foot	$21	$420,000
4	Access road construction/restoration		47,000	square yard	$27	$1,269,000
5	River bank restoration					
	5a	River bank backfill	15,000	cubic yard	$20	$300,000
	5b	River bank stabilization	56,000	square yard	$40	$2,240,000
6	Habitat enhancement					
	6a	Bioengieered bank soil backfill	7,000	cubic yard	$20	$140,000
	6b	Bioengineered banks	10,000	square yard	$40	$400,000
	6c	Vegetation/restoration	28,000	square yard	$15	$420,000
7	Erosion control (silt fence and curtain)		26,000	linear foot	$5	$130,000
8	Barge/work platform		4	month	$53,500	$214,000
					Subtotal:	$5,782,000
					Engineering fees and project management (13%):	$752,000
					Construction management (6%):	$347,000
					Contingency (20%):	$1,156,000
					Total:	$8,037,000
					Present worth (at 7 percent):	$6,561,000

(See notes on page 2)

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
BANK STABILIZATION - PLAINWELL IMPOUNDMENT

NOTES/ASSUMPTIONS

General

- All costs include material and labor, unless otherwise noted.
- Costs do not include legal fees, permitting, obtaining access, negotiations, or agency oversight.
- Unit costs are in 2000 dollars.
- Costs based on current site information and project understanding. This may change following collection of additional data and/or receipt of Agency input and actual project design.
  Cost estimates are generally developed based on the USEPA guidance document "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study", EPA 540-R-00-002 (OSWER 9355.0-75) dated July 2000.
- Present worth is estimated based on a 7% beginning-of-year discount rate (adjusted for inflation) in accordance with USEPA policy directive entitled "Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis", OSWER Directive No. 9355.3-20 (USEPA, 1993). It is assumed that Year 0 is 2000 and that construction costs occur in 2003 (Year 3).
- Engineering fees, project management and construction management are generally based on percentages shown on Exhibit 5-8 of the EPA guidance document for feasibility study (OSWER 9355.0-075).
- A 20% contingency allowance is included to provide for unforeseen circumstances or variability in estimated areas, volumes, labor and material costs.

Component-Specific

- Mobilization/demobilization (labor, material, equipment, etc.) is based on 3 percent of the sum of items 3 through
- General conditions refer to contractor overhead, project administration, and miscellaneous costs including health and safety and temporary construction trailer facility expenses. This is based on 1.5 percent of the sum of items 3 through 8.
- Clearing refers to clearing of vegetation and debris prior to river bank stabilization.
- Access road costs assume the construction of a 16-foot wide roadway along both sides of the Kalamazoo River with additional ingress and egress and turning areas as needed.
- River bank slope lengths were determined using field-transects, and slope area was obtained by multiplying average slope lengths by distances between adjacent transects. Bank stabilization methods generally consist of the installation of rip-rap or crushed concrete above and below water line. Native sand & gravel backfill will be placed in locally affected areas. Finally, topsoil will be placed on the disturbed areas and the restored areas revegetated.
- Bank stabilization measures that includes hard armor elements will generally be covered with soil and revegetated with native emergent herbaceous species at the water line and herbaceous plants and woody shrubs above the waterline.
- An erosion control fence would be placed along the length of the river bank, on both sides.
- Stabilization activities will be performed by means of a barge where river depths allow, and where access from shore is not suitable. Costs associated with a barge/work platform include an excavator mounted on a stationary barge and transport barge for ferrying materials and personnel to the stationary barge.

TABLE 2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
BANK STABILIZATION - OTSEGO IMPOUNDMENT

Item No.	Description		Quantity	Unit	Unit Cost (rounded)	Item Cost (rounded)
1	Mobilization/demobilization		1	lump sum	$189,000	$189,000
2	General conditions		1	lump sum	$95,000	$95,000
3	Clearing		22,000	linear foot	$21	$462,000
4	Access road construction/restoration		52,000	square yard	$27	$1,404,000
5	River bank restoration					
	5a	River bank backfill	20,000	cubic yard	$20	$400,000
	5b	River bank stabilization	64,000	square yard	$40	$2,560,000
6	Habitat enhancement					
	6a	Bioengieered bank soil backfill	8,000	cubic yard	$20	$160,000
	6b	Bioengineered banks	12,000	square yard	$40	$480,000
	6c	Vegetation/restoration	32,000	square yard	$15	$480,000
7	Erosion control (silt fence and curtain)		29,000	linear foot	$5	$145,000
8	Barge/work platform		4	month	$53,500	$214,000
					Subtotal:	$6,589,000
					Engineering fees and project management (13%):	$857,000
					Construction management (6%):	$395,000
					Contingency (20%):	$1,318,000
					Total:	$9,159,000
					Present worth (at 7 percent):	$6,987,000

(See notes on page 2)

TABLE 2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
BANK STABILIZATION - OTSEGO IMPOUNDMENT

NOTES/ASSUMPTIONS

General

- All costs include material and labor, unless otherwise noted.
- Costs do not include legal fees, permitting, obtaining access, negotiations, or agency oversight.
- Unit costs are in 2000 dollars.
- Costs based on current site information and project understanding. This may change following collection of additional data and/or receipt of Agency input and actual project design.
- Cost estimates are generally developed based on the USEPA guidance document "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study", EPA 540-R-00-002 (OSWER 9355.0-75) dated July 2000.
- Present worth is estimated based on a 7% beginning-of-year discount rate (adjusted for inflation) in accordance with USEPA policy directive entitled "Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis", OSWER Directive No. 9355.3-20 (USEPA, 1993). It is assumed that Year 0 is 2000 and that construction costs occur in 2004 (Year 4).
- Engineering fees, project management and construction management are generally based on percentages shown on Exhibit 5-8 of the EPA guidance document for feasibility study (OSWER 9355.0-075).
- A 20% contingency allowance is included to provide for unforeseen circumstances or variability in estimated areas, volumes, labor and material costs.

Component-Specific

- Mobilization/demobilization (labor, material, equipment, etc.) is based on 3 percent of the sum of items 3 through 8.
- General conditions refer to contractor overhead, project administration, and miscellaneous costs including health and safety and temporary construction trailer facility expenses. This is based on 1.5 percent of the sum of items 3 through 8.
- Clearing refers to clearing of vegetation and debris prior to river bank stabilization.
- Access road costs assume the construction of a 16-foot wide roadway along both sides of the Kalamazoo River with additional ingress and egress and turning areas as needed.
- River bank slope lengths were determined using field-transects, and slope area was obtained by multiplying average slope lengths by distances between adjacent transects. Bank stabilization methods generally consist of the installation of rip-rap or crushed concrete above and below water line. Native sand & gravel backfill will be placed in locally affected areas. Finally, topsoil will be placed on the disturbed areas and the restored areas revegetated.
- Bank stabilization measures that includes hard armor elements will generally be covered with soil and revegetated with native emergent herbaceous species at the water line and herbaceous plants and woody shrubs above the waterline.
- An erosion control fence would be placed along the length of the river bank, on both sides.
- Stabilization activities will be performed by means of a barge where river depths allow, and where access from shore is not suitable. Costs associated with a barge/work platform include an excavator mounted on a stationary barge and transport barge for ferrying materials and personnel to the stationary barge.

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
BANK STABILIZATION - TROWBRIDGE IMPOUNDMENT

Item No.	Description		Quantity	Unit	Unit Cost (rounded)	Item Cost (rounded)
1	Mobilization/demobilization		1	lump sum	$548,000	$548,000
2	General conditions		1	lump sum	$274,000	$274,000
3	Clearing		63,000	linear foot	$21	$1,323,000
4	Access road construction/restoration		148,000	square yard	$27	$3,996,000
5	River bank restoration					
	5a	River bank backfill	50,000	cubic yard	$20	$1,000,000
	5b	River bank stabilization	190,000	square yard	$40	$7,600,000
6	Habitat enhancement					
	6a	Bioengieered bank soil backfill	23,000	cubic yard	$20	$460,000
	6b	Bioengineered banks	35,000	square yard	$40	$1,400,000
	6c	Vegetation/restoration	95,000	square yard	$15	$1,425,000
6	Erosion control (silt fence and curtain)		83,000	linear foot	$5	$415,000
7	Barge/work platform		12	month	$53,500	$642,000
					Subtotal:	$19,083,000
					Engineering fees and project management (11%):	$2,099,000
					Construction management (6%):	$1,145,000
					Contingency (20%):	$3,817,000
					Total:	$26,144,000
					Present worth (at 7 percent):	$18,031,000

(See notes on page 2)

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
BANK STABILIZATION - TROWBRIDGE IMPOUNDMENT

NOTES/ASSUMPTIONS

General

- All costs include material and labor, unless otherwise noted.
- Costs do not include legal fees, permitting, obtaining access, negotiations, or agency oversight.
- Unit costs are in 2000 dollars.
- Costs based on current site information and project understanding. This may change following collection of additional data and/or receipt of Agency input and actual project design.
- Cost estimates are generally developed based on the USEPA guidance document "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study", EPA 540-R-00-002 (OSWER 9355.0-75) dated July 2000.
- Present worth is estimated based on a 7% beginning-of-year discount rate (adjusted for inflation) in accordance with USEPA policy directive entitled "Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis", OSWER Directive No. 9355.3-20 (USEPA, 1993). It is assumed that Year 0 is 2000 and that construction costs occur in 2005 and 2006 (Years 5 and 6).
- Engineering fees, project management and construction management are generally based on percentages shown on Exhibit 5-8 of the EPA guidance document for feasibility study (OSWER 9355.0-075).
- A 20% contingency allowance is included to provide for unforeseen circumstances or variability in estimated areas, volumes, labor and material costs.

Component-Specific

- *Mobilization/demobilization (labor, material, equipment, etc.) is based on 3 percent of the sum of items 3 through 8.*
- General conditions refer to contractor overhead, project administration, and miscellaneous costs including health and safety and temporary construction trailer facility expenses. This is based on 1.5 percent of the sum of items 3 through 8.
- Clearing refers to clearing of vegetation and debris prior to river bank stabilization.
- Access road costs assume the construction of a 16-foot wide roadway along both sides of the Kalamazoo River with additional ingress and egress, and turning areas as needed.
- River bank slope lengths were determined using field-transects, and slope area was obtained by multiplying average slope lengths by distances between adjacent transects. Bank stabilization methods generally consist of the installation of rip-rap or crushed concrete above and below water line. Native sand & gravel backfill will be placed in locally affected areas. Finally, topsoil will be placed on the disturbed areas and the restored areas revegetated.
- Bank stabilization measures that includes hard armor elements will generally be covered with soil and revegetated with native emergent herbaceous species at the water line and herbaceous plants and woody shrubs above the waterline.
- An erosion control fence would be placed along the length of the river bank, on both sides.
- Stabilization activities will be performed by means of a barge where river depths allow, and where access from shore is not suitable. Costs associated with a barge/work platform include an excavator mounted on a stationary barge and transport barge for ferrying materials and personnel to the stationary barge.

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

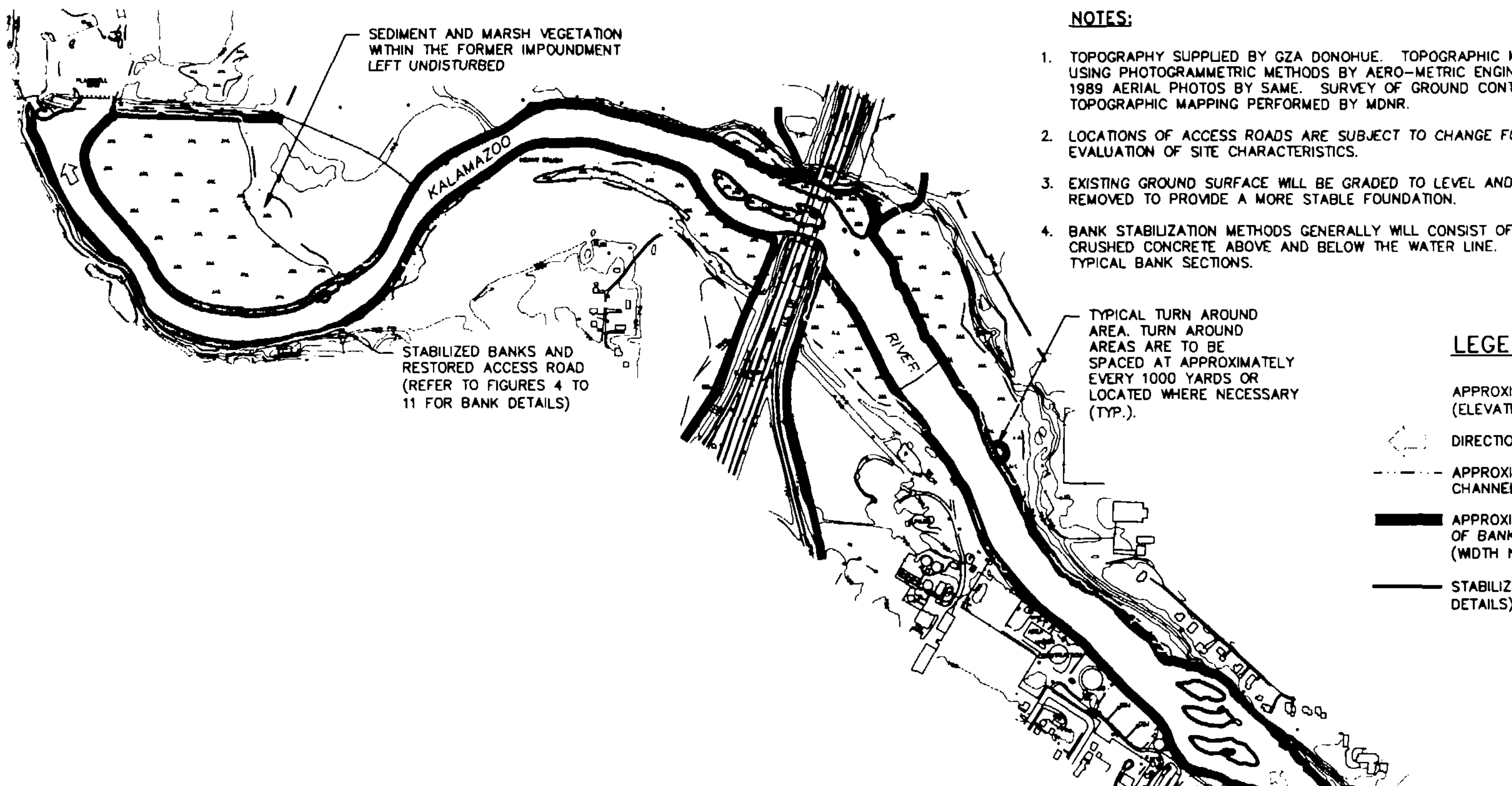
FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE - SUMMARY TABLE
BANK STABILIZATION

Impoundment	Year	Capital Cost	Discount Factor (7%)	Present Worth
Plainwell	3	$8,037,000	0.816	$6,561,000
Otsego	4	$9,159,000	0.763	$6,987,000
Trowbridge	5	$13,072,000	0.713	$9,320,000
	6	$13,072,000	0.666	$8,710,000
	Subtotal	$26,144,000		$18,030,000
	Grand Total:	$43,340,000		$31,578,000

Note:
Present worth is estimated based on a 7 percent (%) beginning-of-year discount rate. Year 0 is assumed to be 2000.

Figures

BLASLAND, BOUCK & LEE, INC.
engineers & scientists



NOTES:

1. TOPOGRAPHY SUPPLIED BY GZA DONOHUE. TOPOGRAPHIC MAPPING PRODUCED USING PHOTOGRAMMETRIC METHODS BY AERO-METRIC ENGINEERING, INC. USING 1989 AERIAL PHOTOS BY SAME. SURVEY OF GROUND CONTROL POINTS FOR TOPOGRAPHIC MAPPING PERFORMED BY MDNR.
2. LOCATIONS OF ACCESS ROADS ARE SUBJECT TO CHANGE FOLLOWING A MORE COMPLETE EVALUATION OF SITE CHARACTERISTICS.
3. EXISTING GROUND SURFACE WILL BE GRADED TO LEVEL AND IN SOME AREAS, TOP SOIL WILL BE REMOVED TO PROVIDE A MORE STABLE FOUNDATION.
4. BANK STABILIZATION METHODS GENERALLY WILL CONSIST OF THE INSTALLATION OF RIPRAP OF CRUSHED CONCRETE ABOVE AND BELOW THE WATER LINE. REFER TO FIGURES 4 TO 11 FOR TYPICAL BANK SECTIONS.

LEGEND

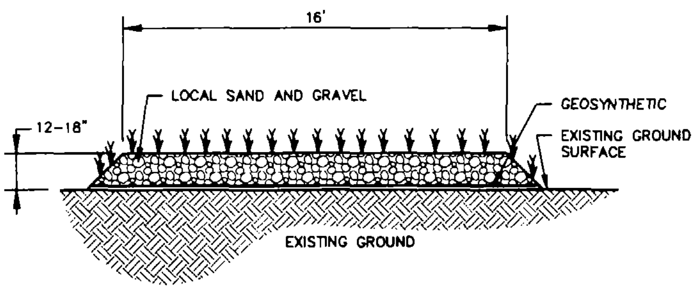
APPROXIMATE FORMER IMPOUNDMENT (ELEVATION 712)

DIRECTION OF FLOW

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE ANTICIPATED LOCATION OF BANK ACCESS ROAD (WIDTH NOT TO SCALE)

STABILIZED BANK (SEE FIGURES 4 TO 11 FOR DETAILS)



RESTORED ACCESS ROAD WITH HABITAT ENHANCEMENTS

NOT TO SCALE

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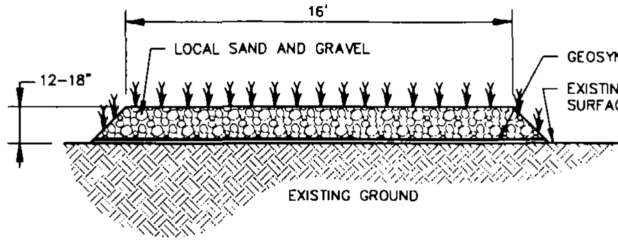
FOR STATE AND FEDERAL REVIEW

KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FEASIBILITY STUDY REPORT

FORMER PLAINWELL IMPOUNDMENT CONCEPTUAL PLAN FOR RIVER BANK STABILIZATION

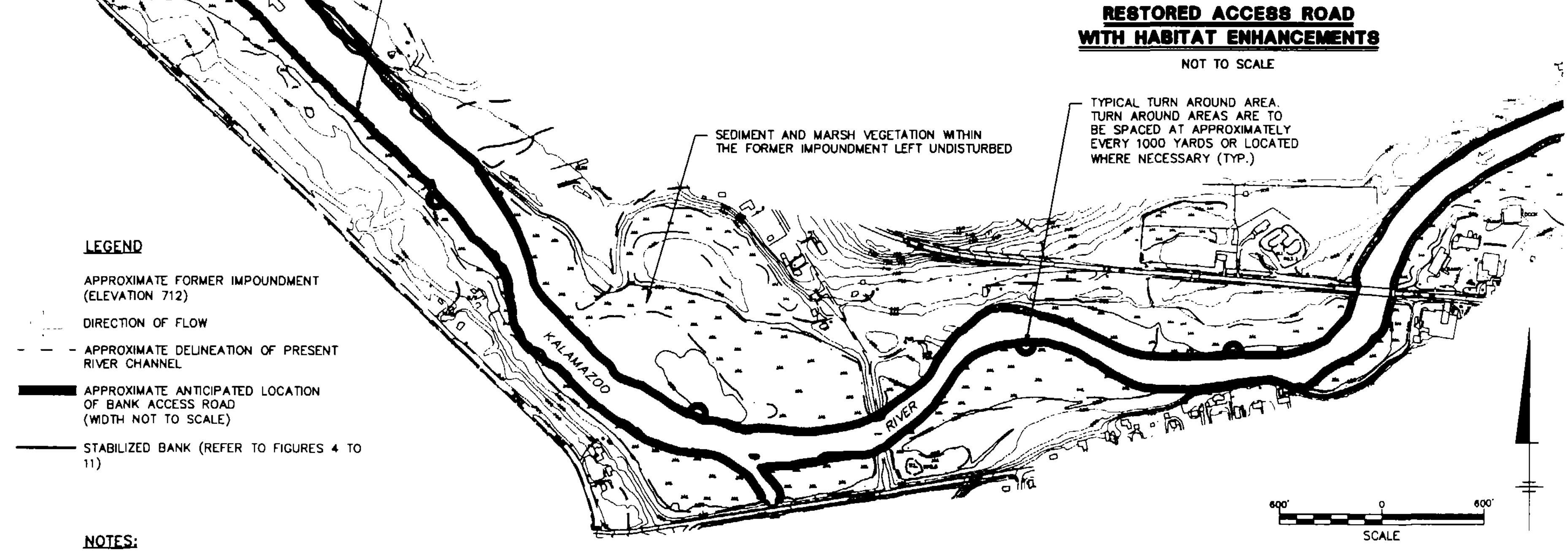
BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 1



RESTORED ACCESS ROAD WITH HABITAT ENHANCEMENTS

NOT TO SCALE



LEGEND

- APPROXIMATE FORMER IMPOUNDMENT (ELEVATION 712)
- DIRECTION OF FLOW
- APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL
- APPROXIMATE ANTICIPATED LOCATION OF BANK ACCESS ROAD (WIDTH NOT TO SCALE)
- STABILIZED BANK (REFER TO FIGURES 4 TO 11)

NOTES:

1. TOPOGRAPHY SUPPLIED BY GZA DONOHUE. TOPOGRAPHIC MAPPING PRODUCED USING PHOTOGRAMMETRIC METHODS BY AERO-METRIC ENGINEERING, INC. USING 1989 AERIAL PHOTOS BY SAME. SURVEY OF GROUND CONTROL POINTS FOR TOPOGRAPHIC MAPPING PERFORMED BY MDNR.
2. LOCATIONS OF ACCESS ROADS ARE SUBJECT TO CHANGE FOLLOWING A MORE COMPLETE EVALUATION OF SITE CHARACTERISTICS.
3. EXISTING GROUND SURFACE WILL BE GRADED TO LEVEL AND IN SOME AREAS, TOP SOIL WILL BE REMOVED TO PROVIDE A MORE STABLE FOUNDATION.
4. BANK STABILIZATION METHODS GENERALLY WILL CONSIST OF THE INSTALLATION OF RIPRAP OF CRUSHED CONCRETE ABOVE AND BELOW THE WATER LINE. REFER TO FIGURES 4 TO 11 FOR TYPICAL BANK SECTIONS.

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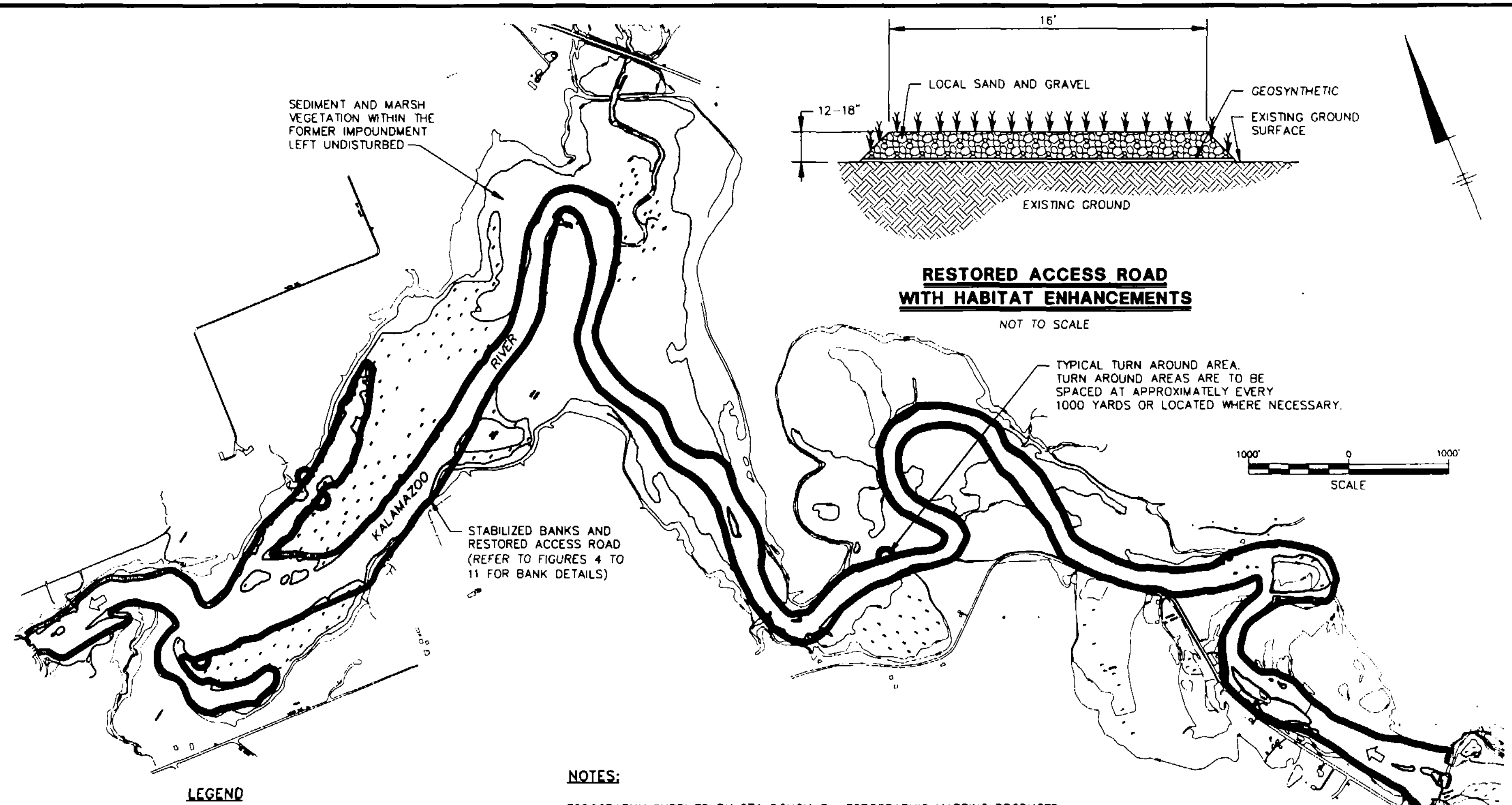
FOR STATE AND FEDERAL REVIEW

KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FEASIBILITY STUDY REPORT

FORMER OTSEGO IMPOUNDMENT CONCEPTUAL PLAN FOR RIVER BANK STABILIZATION

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 2



LEGEND

APPROXIMATE FORMER IMPOUNDMENT (ELEVATION 712)

DIRECTION OF FLOW

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE ANTICIPATED LOCATION OF BANK ACCESS ROAD (WIDTH NOT TO SCALE)

STABILIZED BANK (REFER TO FIGURES 4 TO 11)

NOTES:

1. TOPOGRAPHY SUPPLIED BY GZA DONOHUE. TOPOGRAPHIC MAPPING PRODUCED USING PHOTOGRAMMETRIC METHODS BY AERO-METRIC ENGINEERING, INC. USING 1989 AERIAL PHOTOS BY SAME. SURVEY OF GROUND CONTROL POINTS FOR TOPOGRAPHIC MAPPING PERFORMED BY MDNR.
2. LOCATIONS OF ACCESS ROADS ARE SUBJECT TO CHANGE FOLLOWING A MORE COMPLETE EVALUATION OF SITE CHARACTERISTICS.
3. EXISTING GROUND SURFACE WILL BE GRADED TO LEVEL AND IN SOME AREAS, TOP SOIL WILL BE REMOVED TO PROVIDE A MORE STABLE FOUNDATION.
4. BANK STABILIZATION METHODS GENERALLY WILL CONSIST OF THE INSTALLATION OF RIPRAP OF CRUSHED CONCRETE ABOVE AND BELOW THE WATER LINE. REFER TO FIGURES 4 TO 11 FOR TYPICAL BANK SECTIONS.

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KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FEASIBILITY STUDY REPORT

FORMER TROWBRIDGE IMPOUNDMENT CONCEPTUAL PLAN FOR RIVER BANK STABILIZATION

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 3

X: NONE
L: ON=*, OFF=REF*,SP-TOC
P: SPEC.PCP
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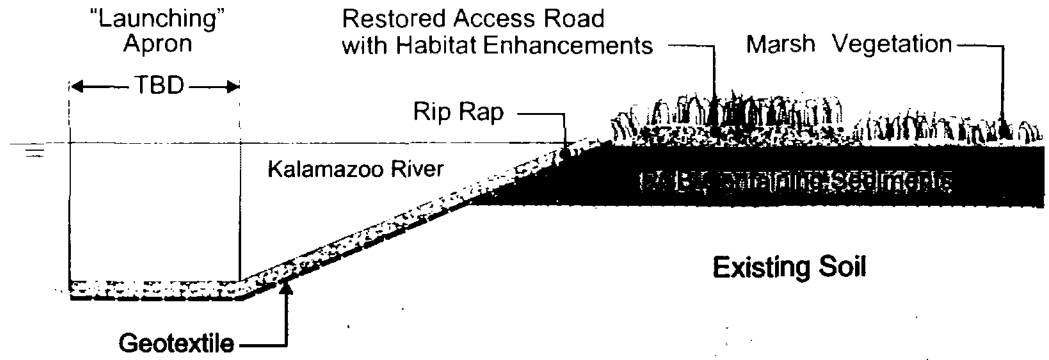
84524840/84524003.DWG



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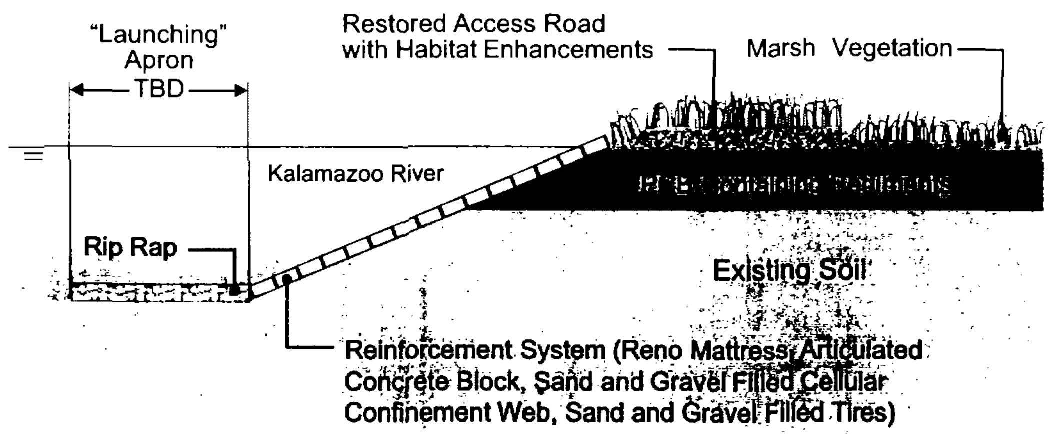

OPTION B

NOT TO SCALE

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KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

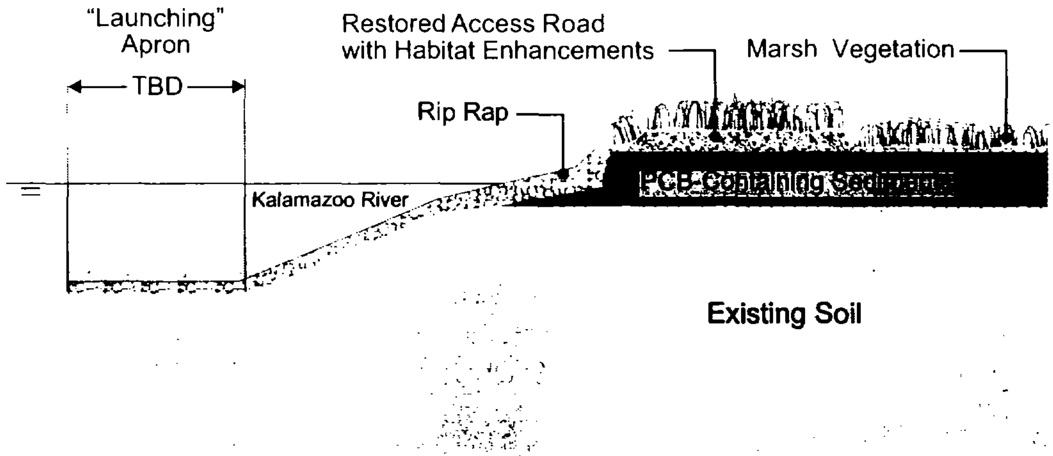
FEASIBILITY STUDY REPORT

MARSH VEGETATION BANK TYPE 1

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 4

10/00 SYR-D54-DJH LBR. LAS
64524640/64524n01 cdr



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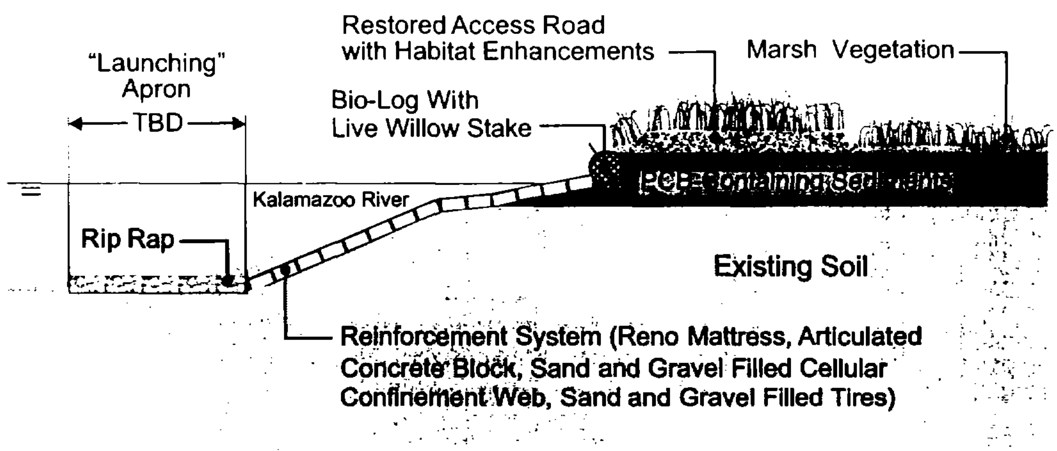

OPTION B

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FOR STATE AND FEDERAL REVIEW

KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

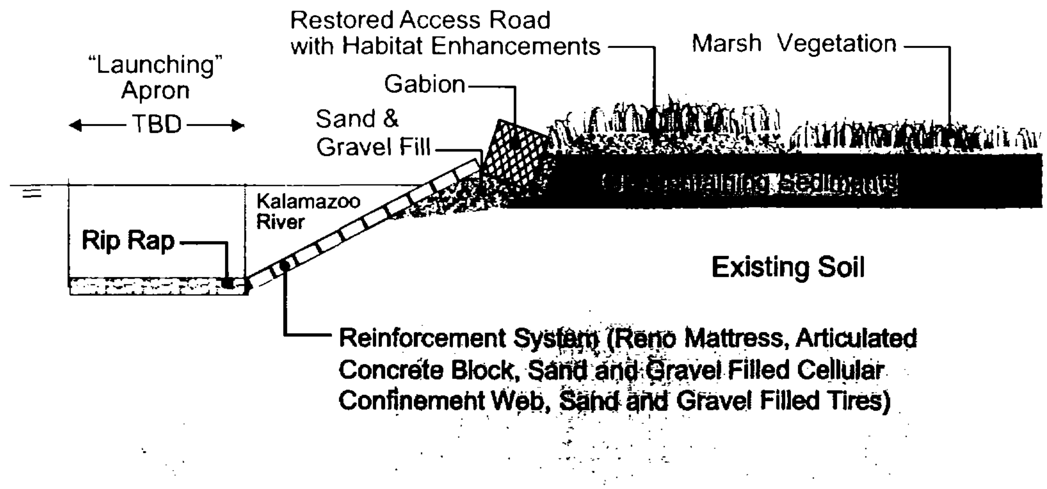
FEASIBILITY STUDY REPORT

MARSH VEGETATION BANK TYPE 2

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 5

08/00 SYR-D54-DJH LBR LAS
64524640/64524n02.cdr



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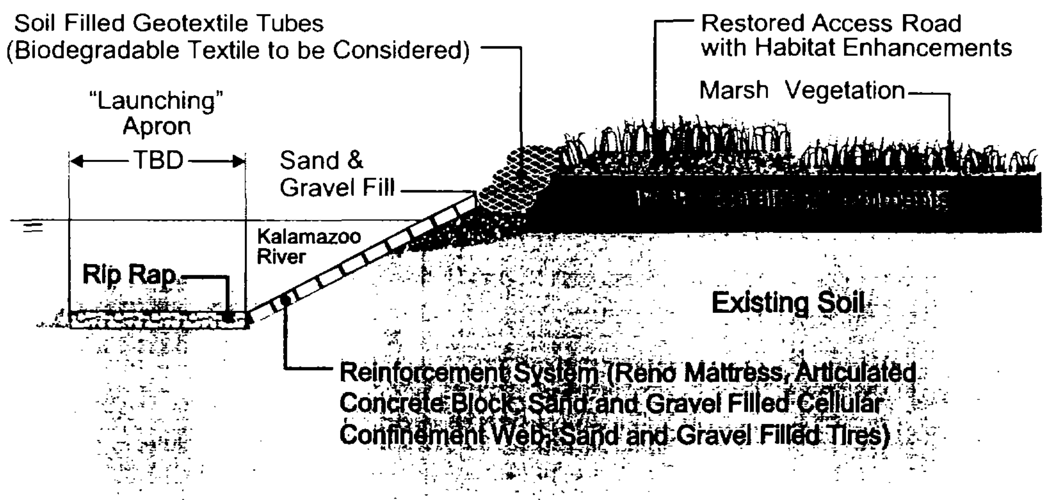

OPTION B

NOT TO SCALE

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FOR STATE AND FEDERAL REVIEW

KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

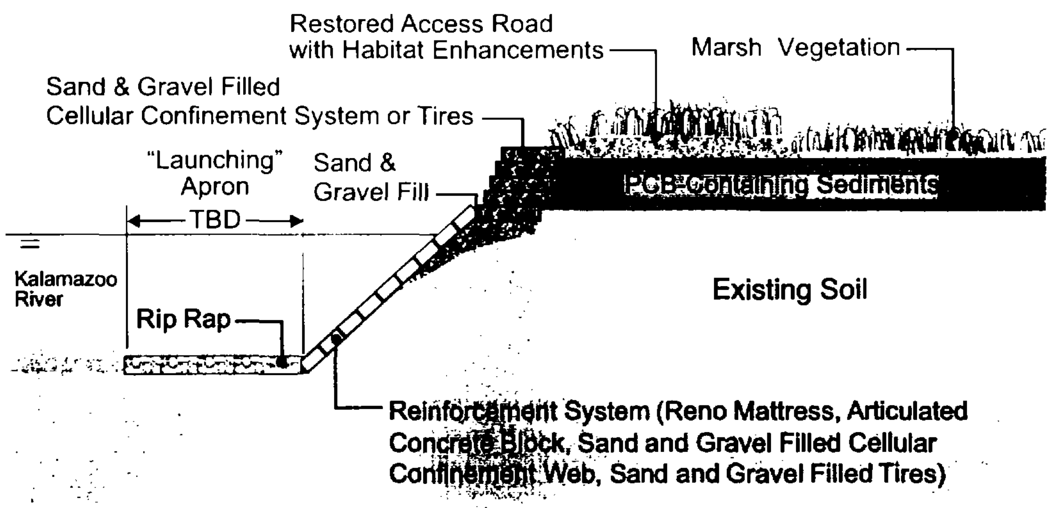
FEASIBILITY STUDY REPORT

**MARSH VEGETATION
BANK TYPE 3**

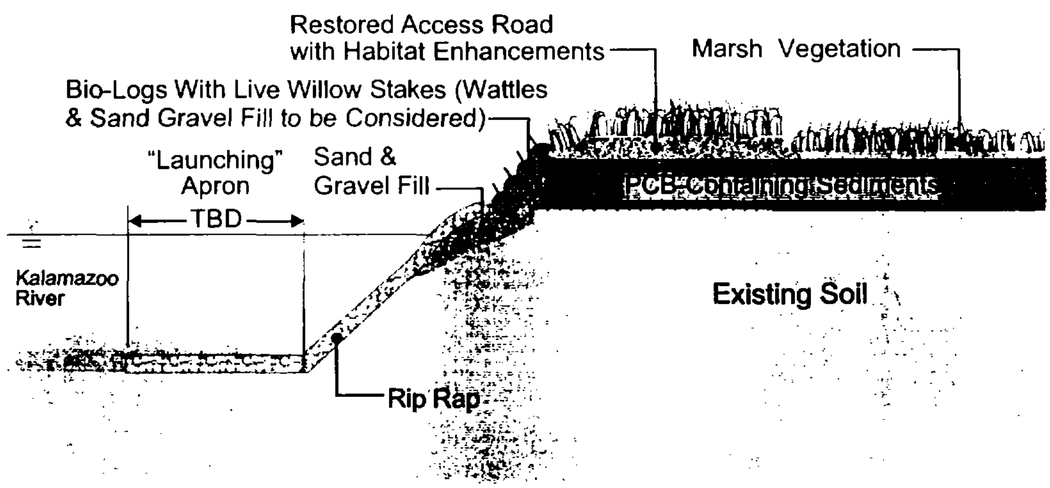
BBL BLASLAND, BOUCK & LEE, INC.
engineers & scientists

FIGURE
6

08/00 SYR-D54-DJH LBR LAS
64524640/64524n03.cdr



OPTION C



OPTION D

NOT TO SCALE

DRAFT
FOR STATE AND FEDERAL REVIEW

KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

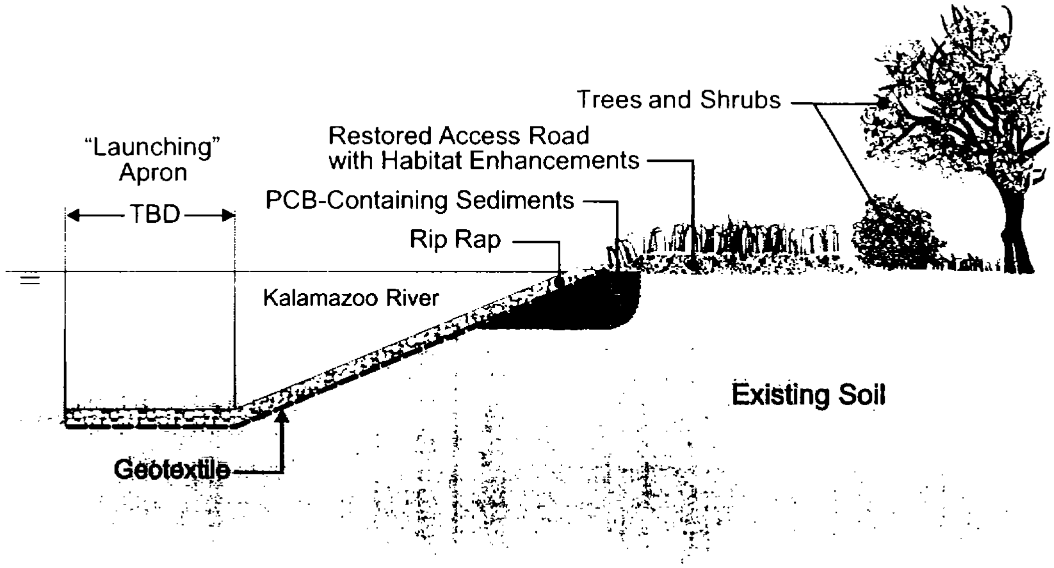
FEASIBILITY STUDY REPORT

MARSH VEGETATION BANK TYPE 3

BBL BLASLAND, BOUCK & LEE, INC
engineers & scientists

FIGURE 7

08/00 SYR-D54-DJH LBR LAS
64524640/64524n04.cdr



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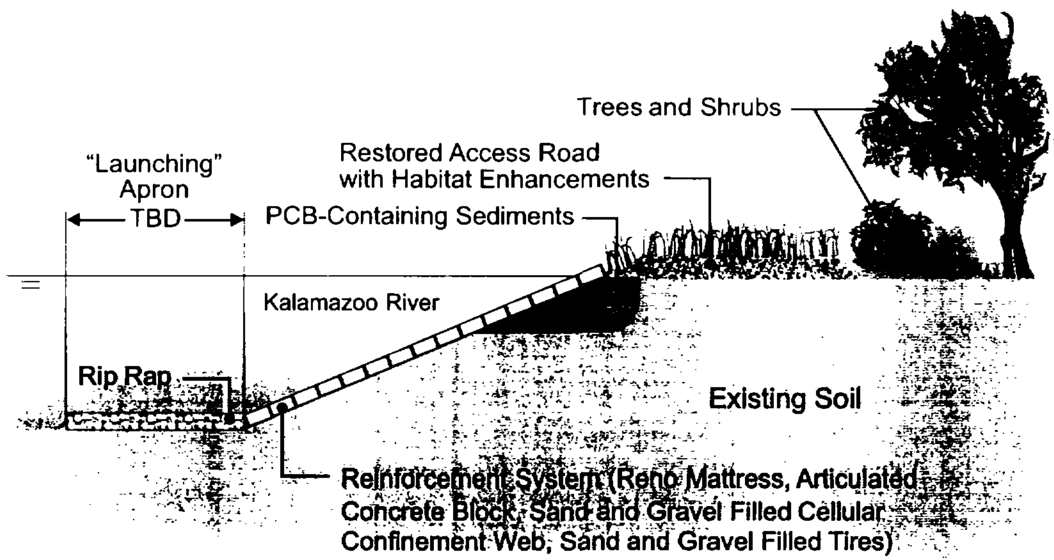

OPTION B

NOT TO SCALE

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FOR STATE AND FEDERAL REVIEW

NOTE:
Erosion protection provided only where erosion impacts PCB-containing sediments.

08/00 SYR-D54-DJH LBR LAS
64524640/64524n05.cdr

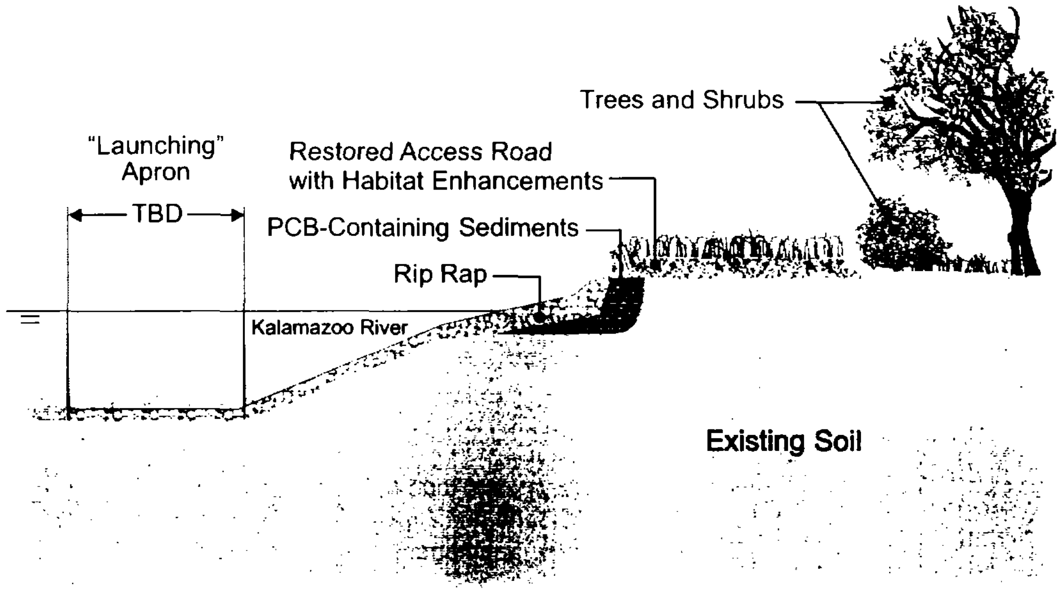
KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT

TREE/SHRUB VEGETATION BANK TYPE 1

BBL BLASLAND, BOUCK & LEE, INC. *engineers & scientists*

FIGURE 8



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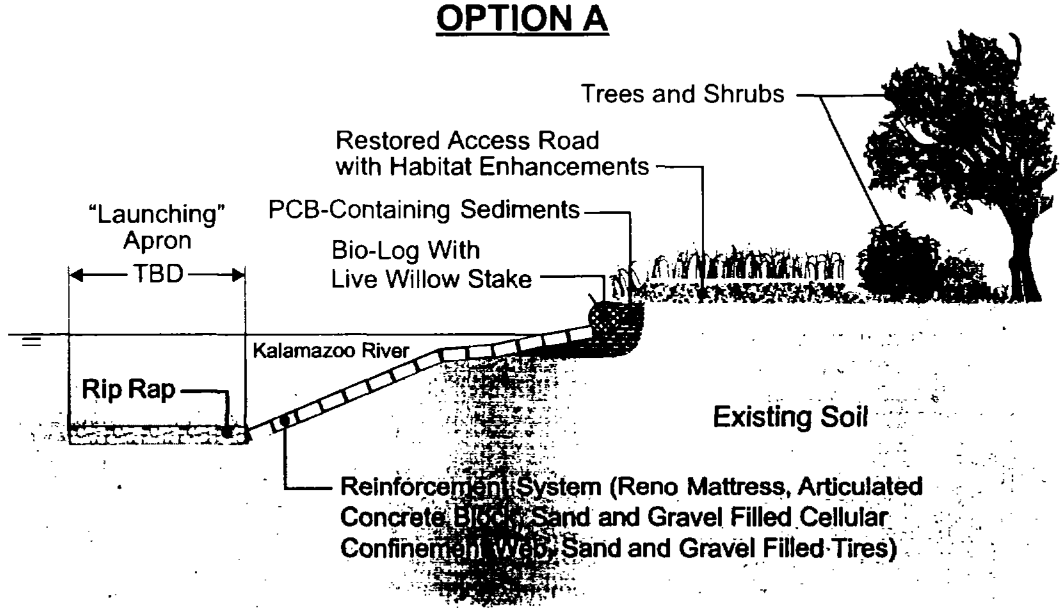


OPTION B

NOT TO SCALE

DRAFT
FOR STATE AND FEDERAL REVIEW

NOTE:
Erosion protection provided only where erosion impacts PCB-containing sediments.

08/00 SYR-D54-DJH LBR LAS
64524640/64524n06.cdr

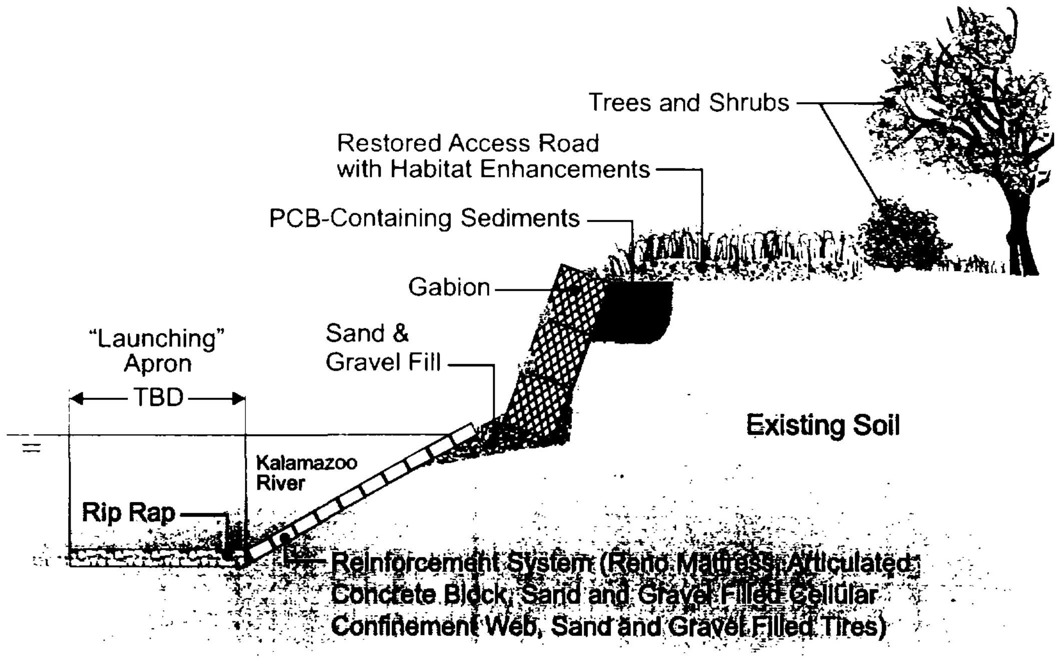
KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT

TREE/SHRUB VEGETATION BANK TYPE 2

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 9



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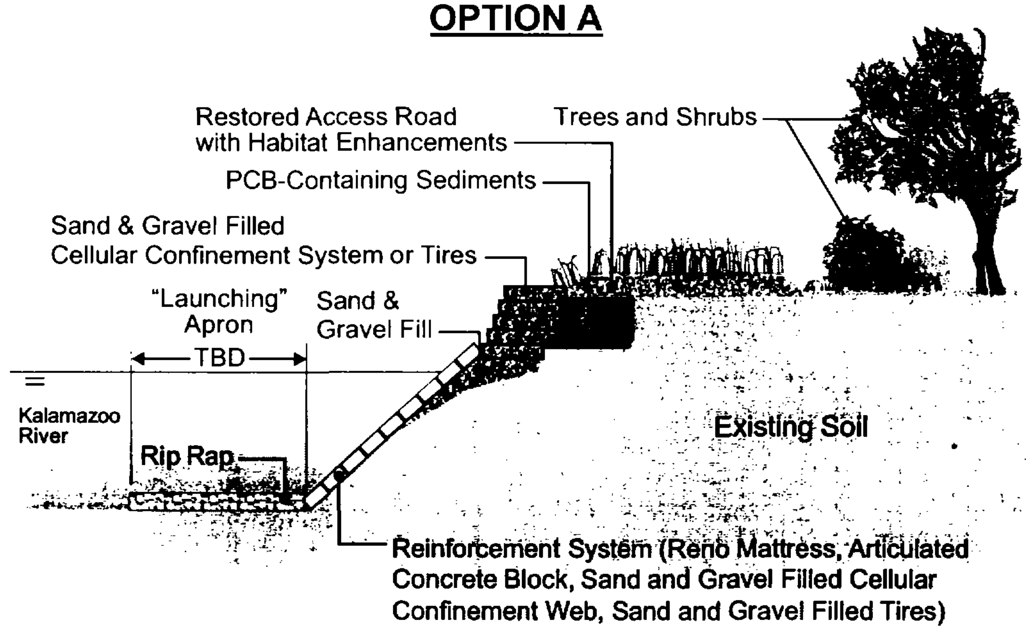

NOT TO SCALE

OPTION B

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FOR STATE AND FEDERAL REVIEW

KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

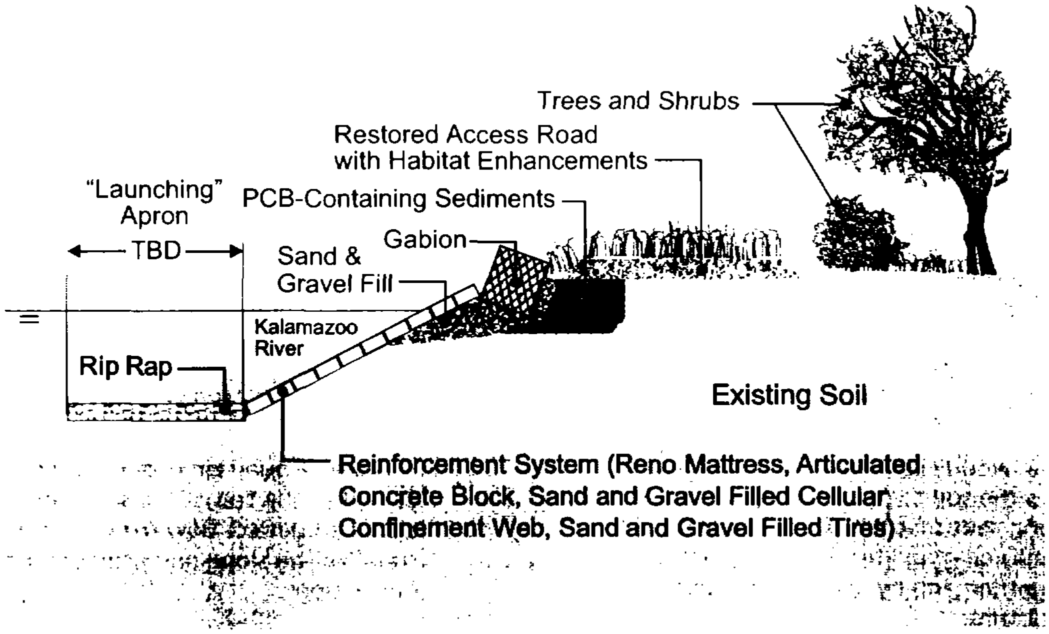
FEASIBILITY STUDY REPORT

TREE/SHRUB VEGETATION BANK TYPE 3

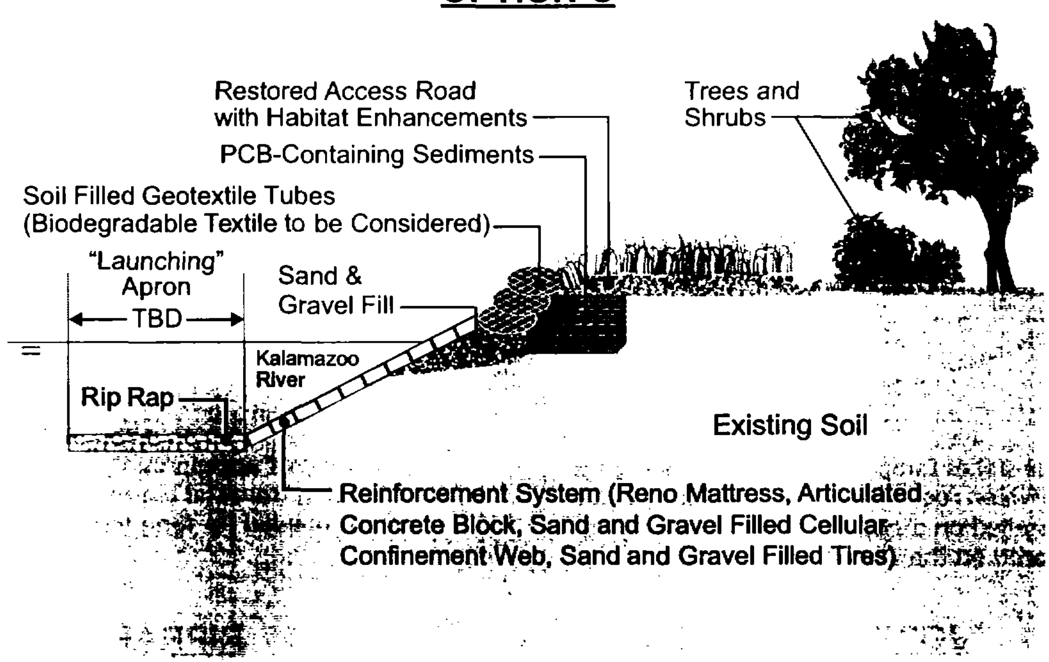
BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE **10**

08/00 SYR-D54-DJH LBR LAS
64524640/64524n08 cdr



OPTION C



NOT TO SCALE

OPTION D

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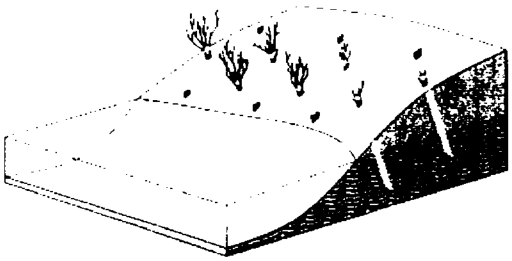
FEASIBILITY STUDY REPORT

TREE/SHRUB VEGETATION
BANK TYPE 3

BBL BLASLAND, BOUCK & LEE, INC.
engineers & scientists

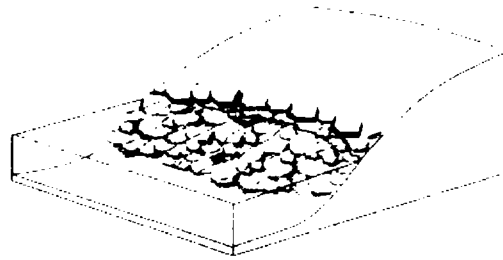
FIGURE
11

10/00 SYR-D54-DJH LBR LAS
64524640/64524n07.cdr



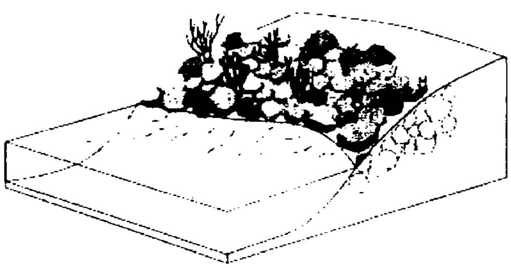
Live, woody cuttings which are tamped into the soil to root, grow and create a living root mat that stabilizes the soil by reinforcing and binding soil particles together, and by extracting excess soil moisture.

LIVE STAKES



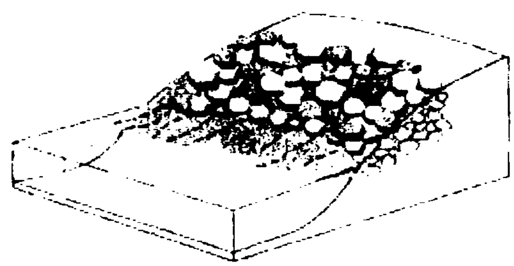
A ridge of quarried rock or stream cobble placed at the toe of the streambank as an armor to deflect flow from the bank, stabilize the slope and promote sediment deposition.

STONE TOE PROTECTION



Live stakes tamped into joints or openings between rock which have previously been installed on a slope or while rock is being placed on the slope face.

JOINT PLANTINGS



A blanket of appropriately sized stones extending from the toe of slope to a height needed for long term durability.

RIPRAP

REFERENCE: Illustrations source: USDA, Stream Restoration: Principles, Processes, and Practices, 1998.

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FEASIBILITY STUDY REPORT

FISH HABITAT ENHANCEMENT MEASURES

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 12

10/00 SYR-D54-DJH
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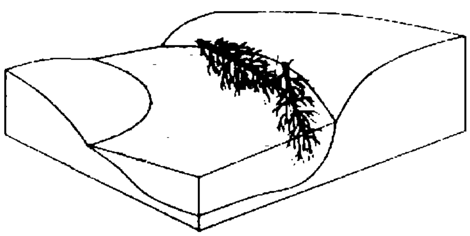
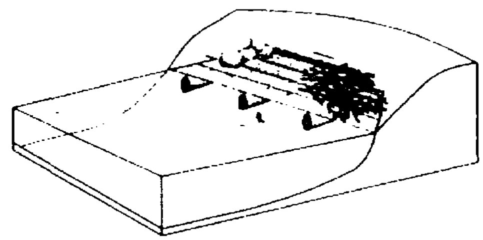


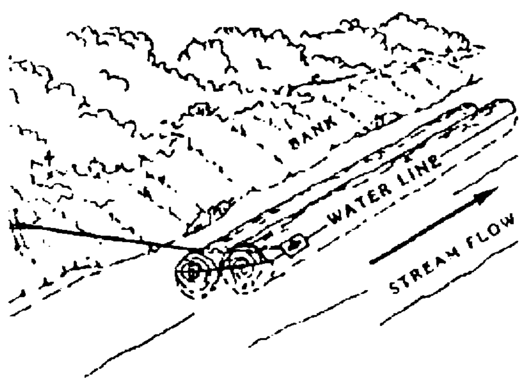
Felled trees placed along the streambank to provide overhead cover, aquatic organism substrate and habitat, stream current deflection, scouring, deposition, and drift catchment.

TREE COVER

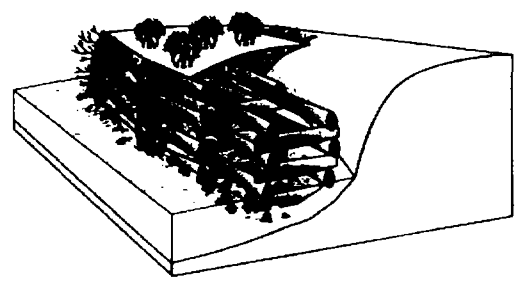


Logs, brush, and rock structures installed in the lower portion of streambanks to enhance fish habitat, encourage food web dynamics, prevent streambank erosion, and provide shading.

LOG/BRUSH/ROCK SHELTERS



FLOATING LOG *



Hollow, box-like interlocking arrangements of untreated log or timber members filled above baseflow with alternate layers of soil material and live branch cuttings that root and gradually take over the structural functions of the wood members.

LIVE CRIBWALLS

REFERENCE: Illustrations sources: USDA, Stream Restoration: Principles, Processes, and Practices, 1998 and * Dave Rosgen, Applied River Morphology, (1996).

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FEASIBILITY STUDY REPORT

FISH HABITAT
ENHANCEMENT MEASURES

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 13

10/00 SYR-D54-DJH
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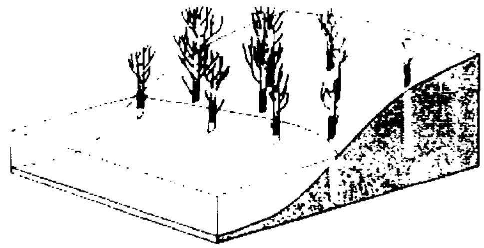
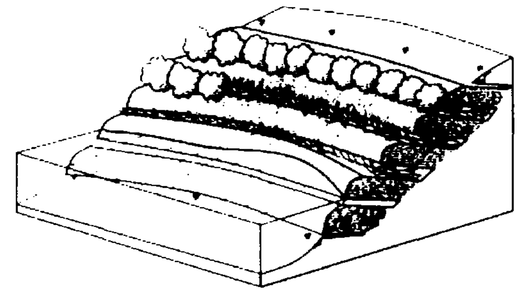


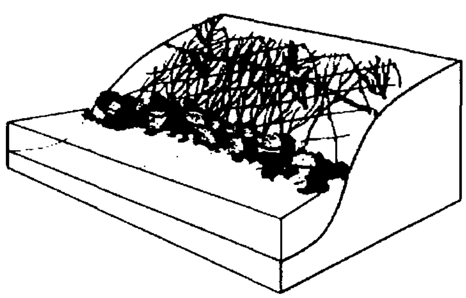
Plantings of cottonwood, willow, poplar, or other species embedded vertically into streambanks to increase channel roughness, reduce flow velocities near the slope face, and trap sediment.

DORMANT POST PLANTINGS



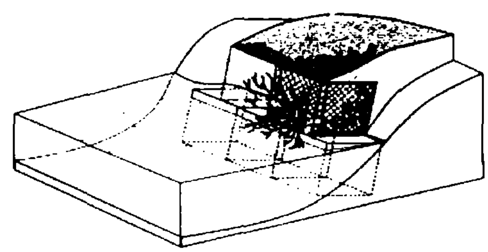
Alternating layers of live branch cuttings and compacted soil with natural or synthetic geotextile materials wrapped around each soil lift to rebuild and vegetate eroded streambanks.

VEGETATED GEOGRIDS



Combination of live stakes, live facines, and branch cuttings installed to cover and physically protect streambanks; eventually to sprout and establish numerous individual plants.

BRUSH MATTRESS



Wire-mesh, rectangular baskets filled with small to medium size rock and soil and laced together to form a structural toe or sidewall. Live branch cuttings are placed on each consecutive layer between the rock filled baskets to take root, consolidate the structure, and bind it to the slope.

VEGETATED GABIONS

REFERENCE: Illustrations source: USDA, Stream Restoration: Principles, Processes, and Practices, 1998.

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FEASIBILITY STUDY REPORT

FISH HABITAT ENHANCEMENT MEASURES

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FIGURE 14

10/00 SYR-D54-DJH
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Appendix C

BLASLAND, BOUCK & LEE, INC.
engineers & scientists

Considerations for Developing the Submerged Sediment Capping Alternative

Appendix C – Considerations for Developing the Submerged Sediment Capping Alternative

This appendix presents information considered during development of Alternative 4 in the Feasibility Study (FS). First, the overall effectiveness of sediment capping/armoring based on the consideration of experiences at other sites with both bench-scale testing and full-scale application is discussed. This is followed by a discussion of the design criteria for a subaqueous cap with specific application to the *Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site* (Site).

In-place containment is an effective way to isolate sediment contaminants from river/harbor areas and resident biota, as demonstrated through both laboratory studies and full-scale implementation. These demonstrations have shown that, when properly designed and constructed, in-place containment systems are capable of mitigating exposure to potential environmental receptors and resisting erosive forces (i.e., flood flows), chemical migration, and bioturbation (mixing of surficial sediments due to biological activity). Studies and examples of full-scale implementation of in-place containment, including United States Army Corps of Engineers (USACE) bench-scale studies, laboratory studies conducted by Louisiana State University (LSU) and full-scale/pilot-study in-place containment (existing and proposed) applications at various sites are discussed below. The effective containment of various constituents of concern are represented, including, but not limited to, polychlorinated biphenyls (PCB), polynuclear aromatic hydrocarbons (PAHs), and metals. The compilation of these studies and site applications of in-place containment led to the development of formal guidance for the design of sediment caps for the remediation of contaminated sediments (Palermo et al., 1998).

Implementation Issues

Although in-place containment is an effective remedial technology, significant implementability issues must be fully considered when evaluating the potential river-wide capping of sediment in the Kalamazoo River. No known river capping project has approached the scale of the combined sediment area in the current and former impoundments and free-flowing reaches at the Site, which is nearly 2,900 acres. Placement of large sheets of geotextile, which are most commonly used in the dry or in small sheets, would present serious challenges during construction, particularly in deep areas like Lake Allegan. In addition, limited access, the presence of debris, variable flows, and insufficient water depths in some reaches would make it difficult to place a uniform layer of cap material on the river bottom.

Substantial volumes of cover materials (up to 10 million cubic yards [cy]) and associated construction equipment would be required over a prolonged period of time (several decades). The availability of certain types of the required materials (e.g., specific sizes of gravel) appears to be limited in the vicinity of the Site. The use of alternate materials or sources of materials would need to be evaluated further during detailed design.

Average water depths in the various segments of the Kalamazoo River vary between two and seven feet (see Table 2 in Appendix E). In the shallower areas, placement of capping materials would significantly alter the natural hydraulics of the river, causing a substantial decrease in flood storage capacity. The low average water depths could limit the thickness of the cap that can be placed and could, therefore, result in a less effective barrier. In addition, placement of two feet of material in shallow nearshore areas could extend the riverbank, thereby reducing river width.

USACE Sediment Capping/Armoring

This section provides a discussion of how in-place sediment containment has been used as an effective way to isolate sediment contaminants from river and resident biota based on extensive laboratory testing.

Capping/armoring is a technique in which affected sediments are covered with a protective layer of clean material. This technology has been studied by the USACE both in bench-scale studies and full-scale applications. The USACE has performed both small- and large-scale laboratory (bench) testing at the Waterways Experiment Station (WES) in Vicksburg, Mississippi, evaluating the effectiveness of using a variety of cover materials in varying thicknesses. PCB-containing sediments from a number of waterways were tested by the USACE at WES, including sediments from New Bedford Harbor, Black Rock Harbor, Indiana Harbor, Duwamish Waterway, and Dutch Kills.

Two design tasks are typically performed to evaluate the effectiveness of the sediment-armoring system. In the first task, an evaluation is conducted to determine the minimum cap thickness required to prevent chemical migration of constituents from sediments into the water column. In the second task, a determination is made of the minimum cap thickness necessary to isolate affected sediments from the water column and biota (clams, fish, and/or burrowing polychaetes typically are used). Experimental systems are typically used to complete these tasks. A number of small-scale (22.6 liter) testing units are used for the first task to evaluate various conditions. Typically, approximately 10 centimeters (cm) of affected sediments are placed in the vessel and covered with cap material (sand, clean dredged material, silts, etc.) of differing thicknesses. The remainder of the vessel is filled with water (saline water or fresh water) representative of site conditions. Control vessels containing only sediment and cap material also are used.

The overlying water is mixed to avoid development of concentration gradients, and the water is monitored for chemical constituents. The USACE usually monitors movement of soluble tracers, such as ammonium-nitrogen or orthophosphate-phosphorus. If the cap prevents movement of the soluble tracers, then it also will prevent movement of compounds that are strongly adsorbed to sediment, such as PCB. If this is the case, then a cap similar to what was tested could be assumed to be effective for PCB containment. The overlying water also can be analyzed for PCB and other compounds of concern. These small-scale studies do not evaluate effects of bioturbation, burrowing organisms, or hydrodynamic forces (USACE, 1996).

The second design task can be completed using larger-scale (250 liter) reactor units that provide water flow and aeration of water. Biota are used in the vessel to evaluate bioturbation effects on cap effectiveness and bioavailability of constituents of concern. Clams and fish have been used to evaluate the uptake of constituents in the water column, while crayfish and burrowing polychaetes have been used to provide bioturbation and evaluate uptake of chemical constituents. As with the first experiment, a number of cap materials of varying thicknesses can be evaluated. The experiment does not assess the effects of hydrodynamic forces.

Sturgis and Gunnison (1988) used the small-scale units to evaluate the effectiveness of capping New Bedford Harbor sediments (sediments containing 2,167 parts per million [ppm] PCB were tested). This evaluation used "clean" sediments from the harbor as a capping medium and concluded that a 35-cm cap was effective in preventing both the release of soluble tracers (ammonium-nitrogen, orthophosphate-phosphorus) and the migration of PCB from New Bedford Harbor sediments into the water column.

Brannon et al. (1985) reported the results of small-scale testing of Black Rock sediments and determined that a 22-cm cap using any of the cap materials tested (New Haven Harbor sediments, washed masonry sand, and Vicksburg silt) was sufficient to prevent chemical exchanges between the Black Rock sediment and the overlying water (in the absence of bioturbation). This study also established that New Haven sediment was more effective than Vicksburg silt, and both were more effective than sand at preventing the release of chemicals from Black Rock sediments into overlying water.

Brannon et al. (1985) also reported results of their evaluation of capping Black Rock sediments (sediments with 18 ppm PCB and 315 ppm PAHs were tested). The study evaluated various cap materials (New Haven Harbor sediments, washed masonry sand, and Vicksburg silt) using the large-scale reactor units. Clams *(Rangia cuneata)* were suspended 4 cm above the cap material, and burrowing polychaetes *(Nereis virens)* were placed on the cap and allowed to migrate into the cap and sediments.

Cap thicknesses of 5 cm and 50 cm were evaluated. It was determined that:

- the 5-cm cap was not totally effective due to bioturbation caused by the polychaetes;
- the Vicksburg silt and New Haven Harbor sediments were more effective than sand in preventing PCB and PAH movement; and
- the 50-cm cap effectively isolated the constituents in underlying sediments from overlying water and biota for all cap materials.

Similar experiments using Buttermilk Channel sediments (containing 1 ppm PCB) as a cap material for isolating Dutch Kills sediment (containing 18 ppm PCB) were performed by Brannon et al. (1986), employing both small- and large-scale testing units. Small-scale tests showed that a cap thickness of 22 cm was sufficient to prevent transfer of dissolved constituents into overlying water.

Clams *(Mercenaria sp.)* and polychaetes *(Nereis virens)* were used in the large-scale tests. The polychaetes penetrated both the 10-cm and 50-cm caps. The clams exhibited an increased uptake of trichlorobiphenyl with the 10-cm cap, but did not exhibit a significant increase in PCB, PAHs, or heavy metals when the 50-cm cap was tested. The study concluded that a 50-cm cap of Buttermilk Channel sediments was effective in preventing the transfer of constituents into overlying water and biota.

Similar experiments also were performed by Gunnison et al. (1987) on sediments from Black Rock Harbor, Dutch Kills, and Indiana Harbor. These experiments followed the procedures identified earlier for both small- and large-scale testing. Biota used in the experiments varied based on conditions being simulated (i.e., fresh or salt water), and included clams (genus and species not identified), yellow perch *(Perca flavescens)*, sandworms *(Nereis virens)*, and crayfish *(Procambarus clarkii)*.

Based on the results of these studies, a 22-cm cap was determined to be generally sufficient to "seal the contaminated sediments from the overlying water column," and a 50-cm cap was "substantiated as being totally effective from both chemical and biological viewpoints" (Gunnison et al., 1987). The 50-cm thickness was based on the combined thickness required for chemical isolation and protection from bioturbation.

The effectiveness of capping Indiana Harbor sediments (containing 22 ppm PCB) using Lake Michigan sediments (containing 0.013 ppm PCB) was studied at the WES Environmental Laboratory (1987). As with other studies, both small- and large-scale testing units were used. The small-scale tests concluded that a 30-cm cap was sufficient in preventing transfer of constituents into overlying water. Yellow perch fingerlings *(Perca flavescens)*, clams *(Anondonta grandis)*, and red swamp crayfish *(Procambarus clarkii)* were used in the large-scale studies, which also evaluated a cap thickness of 30 cm. The 30-cm cap prevented migration of organic constituents (PCB and PAHs) from underlying sediment into the water column and all of the biota tested. The USACE recommended that a minimum cap thickness of 50 cm be used to protect against the effects of deep-burrowing biota.

These studies demonstrate that capping of sediments can provide an effective means of isolating PCB in sediments from the overlying water column and resident biota. Site-specific factors such as hydrodynamic forces, sedimentation rates, and native biota must be considered when designing a cap. Based on the results of the studies presented herein, a 50-cm cap has been shown to effectively provide chemical and biological isolation of the underlying sediment. This thickness is based on the combined thickness required for both chemical isolation and protection from bioturbation in marine sites. Of this 50-cm thickness, the sediment thickness required for chemical isolation only (excluding bioturbation) ranged from 22 to 35 cm.

The USACE also issued a draft document entitled *Design Considerations for Capping/Armoring of Contaminated Sediments In-Place* (Maynord and Oswalt, 1993). The investigation detailed in this document was directed by the Engineering/Technology Work Group (ETWG) following its identification of in-situ capping/armoring as one of the technologies retained for further review under the Assessment and Remediation of Contaminated Sediments (ARCS) program. The document provides technical guidance on the hydraulic design of in-situ capping/armoring systems using riprap. The use of riprap is intended to prevent erosion of the underlying sediment due to the effects of flood flows and propeller wash.

The United States Environmental Protection Agency (USEPA) issued a guidance document under the ARCS Program, entitled, *Guidance for In-Situ Subaqueous Capping of Contaminated Sediments* (Palermo et al., 1998) which provides technical guidance for subaqueous, in-situ capping as a remediation technique for affected sediments. It includes detailed guidance on site and sediment characterization, cap design, equipment and placement techniques, and monitoring and management considerations. This document states that, "capping can remedy adverse effects (e.g., bioaccumulation by benthic organisms and fish) of sediments containing chemical constituents through three primary functions:

a) physical isolation of the affected sediment from the benthic environment;

b) stabilization of the affected sediment, preventing resuspension and transport to other sites; and

c) reduction of the flux of dissolved constituents into the water column." (Palermo et al., 1998)

Also, the National Research Council's Committee (NRC's) on Contaminated Marine Sediments published a book entitled *Contaminated Sediments in Ports and Waterways* (NRC, 1997). This book states that, "in-situ (sediment) management offers the potential advantage of avoiding the costs and material losses associated with the excavation and relocation of sediments. Natural recovery is most likely to be effective where surface concentrations are low and are being covered over rapidly by cleaner sediments, or where other processes destroy or modify the sediment constituents thus decreasing constituent releases to the environment over time. When natural recovery is not feasible, capping may be an appropriate way to reduce bioavailability by minimizing constituent contact with the benthic community" (NRC, 1997).

In addition to these USACE studies, LSU conducted a series of laboratory and mathematical modeling studies regarding the use and effectiveness of in-place containment of sediment containing chemical constituents (Thibodeaux et al., 1990; Wang et al., 1991; and Thoma et al., 1993). It is important to note that the later LSU studies were conducted based on grant funding received from the USEPA Risk Reduction Engineering Laboratory, the states of Cincinnati and Ohio, and the USEPA Hazardous Waste Research Center at LSU. Results of both the USACE and LSU studies support in-place containment/capping and form the basis for design and theoretical analysis of capping alternatives.

In-Place Containment At Other Sites

In-place containment (capping) of constituent-containing sediments is a proven technology which has been implemented at full-scale under a variety of conditions at sites across the United States and elsewhere. Examples of sediment capping for sediment remediation in the United States and Canada are presented below.

AquaBlok™ Capping Demonstration – Ottawa River, Ohio

AquaBlok™, a composite clay-mineral aggregate, was placed as a barrier over contaminated sediments in a 0.2-mile stretch of the Ottawa River in Toledo, Ohio, a tributary of Lake Erie. The primary constituent of concern was reportedly PCB, although sediment PCB concentrations were not available. The stated goals of this demonstration project were to evaluate implementation techniques, analyze costs, and determine quality control procedures necessary to evaluate the maintenance of the required material thickness. Hull & Associates, Inc. served as the lead consultants on the project.

The test site was approximately 2.5 acres in size and consisted of three areas (A, B, and C), each approximately 300 feet long by 120 feet wide (all areas extend across the entire river width). This stretch of the Ottawa River was chosen because it is located at a point where the river is essentially an estuary, exhibiting relatively low flows (the velocity of the 100-year flood event is reported as approximately 4.8 feet per second) and access is readily available is this area. The bank conditions along the test site vary, and consist of rip-rap, sheetpile, and unprotected bank. A seiche is commonly experienced in the test area. Typical sediment depth is four feet, and the typical water depth is eight feet. The sediment generally is composed of silt and clay.

Prior to material placement, a number of field and laboratory tests were conducted to characterize the test area and determine material characteristics conducive to successful placement at the test site. Field data collection consisted of surveying and development of sediment bed cross sections. Sediment samples also were collected and analyzed for grain-size distribution to facilitate the custom manufacture of AquaBlok™ pellets that would be best suited for test area sediment characteristics.

Each of the three test areas was targeted for a different combination of composite construction. AquaBlok™ was the only material placed in Area A. In Area B, a geotextile material was placed under the AquaBlok™. In Area C, a geotextile material overlain with AquaBlok™ was placed as in Area B, then covered with stone. The targeted thickness of AquaBlok™ in each area was four to eight inches (hydrated).

In areas B and C, the geotextile material was sunk to the river bottom using sand bags filled with AquaBlok™. At the test site, material was placed using three methods that included a helicopter (0.5 acres), a "telebelt" conveyor system (1.9 acres), and a dragline operated from shore (0.1 acres). Placement of materials was tested on land prior to water application. River placement began on September 15, 1999 and was completed on September 22, 1999.

Monitoring results associated with the demonstration project are very limited. A pre- and post-placement benthic community assessment will be performed by the Ohio Environmental Protection Agency. The pre-placement assessment indicated that the benthic community in the test area was very limited. The only monitoring conducted during placement was sediment probing to assure the desired material thickness was achieved. The resulting cap thickness was approximately 5-6 inches; core samples indicated a sharp boundary exists at the cap/sediment interface (Hazardous Waste Consultants, 2000). The test area will be probed post-placement (after high flows) to assess the degree of erosion (if any) in the test area.

Convair Lagoon - San Diego, California

Convair Lagoon, located in San Diego Bay, is a 4-hectare area with sediment PCB concentrations up to 1,800 ppm. A final Environmental Impact Report/Remedial Action Plan (EIR/RAP) for the site was issued in October 1993, in which in-situ capping was chosen as the remedial alternative for the embayment. Capping was considered a more viable alternative over a removal and/or treatment option due to the potential release and exposure of the most highly-concentrated sediments during dredging activities.

Cap construction activities were initiated in October 1996, after a substantial amount of submerged debris was removed, and completed in mid-1998. The 5.7 acre cap, in ascending sequence, consists of geogrid, then one foot of crushed rock, then two feet of sand. Eelgrass was planted at the surface. The stiff structural geogrid was floated into position in large integrated panel sections over the site area. Gravel was then spread to sink the geogrid into position at the bottom of the bay. The crushed rock and sand layers were both placed using a clamshell bucket. The outer boundary of the cap was defined by the 4.6 ppm PCB line. Along this boundary, a submerged rock berm was constructed. The purpose of the rock berm was to provide stability during and after placement of the cap. The perimeter berm is a minimum of one foot higher than the cap (maximum 5 feet) and is designed to prevent liquefaction of the cap during a significant seismic event (Maher and Sanders, 1996). Outside of the berm, a 50-foot width of sand that was 3-feet thick tapering to zero was placed at the request of USEPA to cover sediments with PCB concentrations >1 ppm and <4.6 ppm (GE, AEM, and BBL, 2000).

Long-term monitoring (20 to 50 years) of the cap is now in progress and consists of periodic visual inspections by divers as well as cap thickness measurements taken at 30 probe locations. Once per year, cores are obtained at three locations and analyzed to demonstrate that there is no upward migration of PCB (GE, AEM, and BBL, 2000).

Duwamish Waterway - Seattle, Washington

Approximately 840 cubic meters (m^3) of fine-grained silty, clayey, shoal material (containing PCB, metals, and other constituents) were removed from the Duwamish Waterway in Seattle, Washington in March 1984 with a clamshell dredge and relocated into 21 meters (m) of water. The relocated sediments then were capped with 0.6 m (3,100 m^3) of clean sand. Monitoring performed six months after capping indicated that PCB were not migrating through the cap. A well-defined interface between the sediment and the cap was evident both visually and chemically. The cap was monitored again 18 months and 5 years after capping operations were completed. When summarizing the results, Sumeri (1991) concluded "the Duwamish confined aquatic disposal has succeeded in confining the contaminated sediment for five years. The rate of diffusion into the cap is negligible. There is no indication that the cap is degrading from either chemical transport or biological activity." In August of 1995 at the 11-year post-cap monitoring period, results of sediment core chemical analyses suggested that the contaminants were not migrating into the cap sediments (Sumeri, 1996).

Puget Sound - Seattle, Washington

Since 1984, a number of sediment areas have been capped in the Puget Sound, near Seattle, Washington. The methods of cap placement and associated monitoring programs varied with each project. Each of these capping projects is further discussed below. The profiles are useful in that the caps placed at the majority of the sites demonstrated stability and integrity after five years.

One Tree Island Marina

In 1987, a confined aquatic disposal (CAD) area was constructed to dispose of chemical constituent-containing sediments removed during deepening of the marina. The constituents of concern included heavy metals and PAHs (Sumeri, 1996). A conical shaped depression (14 m deep, 46 m in diameter at the top) was dredged into an area containing clean sediment. Sediment containing chemical constituents was dredged and placed into the depression. The dredged sediments were capped with 1,840 m^3 of clean sediment (with a thickness of 1.2 m) from the site. The cap encompasses an area of 0.2 hectares (Sumeri, 1996). "No immediate post-cap chemical monitoring was performed to establish a baseline. However, in 1989, the Department of Energy (DOE) assumed the responsibility of monitoring the project. Four cores were extracted for sediment chemistry. No evidence in the 1.2 m deep core samples was found of the previous contamination. There was no evidence that the cap was being affected by the underlying sediments" (Sumeri, 1996).

Simpson Tacoma Kraft Superfund Site

Shallow, near-shore Commencement Bay sediments close to an industrial outfall containing PAHs and polychlorinated dibenzodioxins (PCDD) and dibenzofurans (PCDF) were the target of the capping action at the Simpson Tacoma Kraft Superfund Site. Part of the remedial action included construction of a cap (1.5 to 6.0 m) over these sediments (Sumeri, 1996). Sand from a sand bar in the nearby Puyallup River was used as capping material. The cap design included the placement of additional material to raise the bay bottom in order to create 2.4 hectares of intertidal habitat, which resulted in the 6.0 m cap thickness in some areas (Sumeri, 1996). In 1988, approximately 6.9 hectares of near-shore sediments were covered with 182,000 m^3 of sand. Following capping activities, annual monitoring since 1993 has shown some level of redistribution of the placed material in the upper elevations of the cap; however, the cap still exceeds the design thickness of 1.2 m, and no significant movement of chemical constituents through the cap has been measured.

Pier 51 - Coleman Ferry Terminal

This 1989 project involved the capping of approximately 1.6 hectares of sediment prior to the renovation and expansion of the Coleman Ferry Terminal (Pier 51) in Elliott Bay. Constituents of concern included metals, PAHs, PCB, and PCDF. Coarse sand (7,700 cubic meters) was obtained from a local quarry and placed using a clamshell dredge and barge to a design cap thickness of 0.5 m. A diver survey performed the week following cap placement indicated that the cap thickness ranged from 0.5 m to 0.6 m. In 1994, another diver survey was performed to inspect the cap; no erosion of the cap was detected (Sumeri, 1996).

Denny Way

This 1990 project conducted in Elliott Bay by the Municipality of Metropolitan Seattle (Metro) and USACE was undertaken to remediate sediment containing a variety of constituents, including PCB, PAHs, and heavy metals. The cap material (15,300 m^3) was dredged from a source in the Duwamish Waterway and subsequently placed over three acres in Denny Way using a split-hull bottom-dump barge. Following cap placement, a five-year monitoring plan, consisting of measurements of cap thickness and collection of sediment cores, was initiated (Metro, 1994a; Sumeri, 1996). The first three years of monitoring results indicate that no erosion has occurred at the cap surface, and no chemicals have migrated into the cap from the underlying sediment.

Pier 53-55

This 1992 capping project, identified as the Pier 53-55 sediment cap, involved the placement of cap materials over a total of 1.8 hectares. Sediments offshore of Pier 53-55 contain heavy metals, PAHs, and PCB (Sumeri, 1996). Cap materials were obtained from the Duwamish Waterway and placed using a split-hull bottom-dump barge. A 0.9 m thick cap (13,600 m^3) covering 1.2 hectares was placed in deeper offshore waters. A 0.3 m thick cap (3,500 m^3) covering 0.6 hectares was placed closer to shore and used to minimize the reduction of navigation depths (Sumeri, 1996). A 10-year monitoring program was initiated after cap placement, and results from the first monitoring round have been made available. Cap thickness measurements showed only minor changes, while core samples revealed a sharp cap/sediment interface. Results show that there is no evidence of constituent movement into the cap materials (Metro, 1994b); however, constituents from an adjacent sediment site have been deposited on the surface of the Pier 53-55 cap.

Pier 64

The Pier 64 cap was constructed in March of 1994. Many of the USEPA priority pollutants including lead, mercury, zinc, low and high molecular weight PAHs, benzoic acid, bis(2-ethylexyl)phthalate, dibenzofuran, and PCB were identified in the sediments in the area. The capping activities consisted of slowly releasing approximately 10,000 m^3 of sand over a 13 hectare area. The cap materials were released in 6.1 to 18 m of water, and the design thickness was 15 to 45 centimeters. The cap was designed to withstand the 0.006 to 0.05 meters per second (m/s) current measured in the area attributed to tidal cycles. Physical monitoring of the cap showed that while most of the cap had maintained its design thickness, the western portion of the cap showed a reduction in cap thickness from 21 cm during placement to 12 cm six months later. No determination has been made as to whether this is from erosion or localized consolidation/settling. Post-capping chemical monitoring have shown that metals, as well as all organic chemical parameters, are well below pre-capping concentrations (Sumeri, 1996).

Eagle Harbor, East Harbor Operable Unit

High concentrations of PAHs were present in the sediments as a result of local wood treatment operations. Between September 1993 and March 1994, USEPA Region 10 and the USACE-Seattle District placed a 0.9 m-thick sand cap over a 22 hectare area in Eagle Harbor across Puget Sound from Seattle. Two different placement methods were used. In the deeper central harbor, material was trickled out of bottom-dump barges. In shallower areas, high-pressure hoses washed the cap material off barge decks, allowing it to settle more gently. Monitoring and evaluation of the cap is ongoing (USEPA, 1994; Sumeri, 1996). According to the USEPA, monitoring of this cap has shown the presence of creosote "marbles," the source of which has not been determined (USEPA, 1999).

<u>Hamilton Harbour – Ontario</u>

This project involves the subaqueous capping of PAH-containing sediment on a 1 hectare site in Hamilton Harbour, Ontario with the placement of 0.5 m of medium to coarse clean sand over a very soft, black, silty clay (Palermo et al., 1996). Selection criteria evaluated for this capping project included the stability of capping material and ship traffic effects. As part of the cap design criteria, chemical isolation and sediment consolidation were evaluated. It was concluded that, based on initial calculations and analysis, subaqueous capping would be a feasible and effective remedial option for this portion of Hamilton Harbour, where, due to the large sediment volume, it would be impractical to implement dredging and upland disposal (Zeman, 1993).

General Motors Superfund Site - Massena, New York

In 1995, 10,600 m^3 of PCB-containing materials were dredged from a St. Lawrence River embayment as part of the remediation of the General Motors site. In a 0.7 hectare area of the site/embayment, the remedial objective of a final sediment PCB concentration of 10 ppm could not be achieved by repeated dredging. The average residual post-dredging PCB concentration was 27 ppm (dry weight) and ranged between 0.6 and 91 ppm (dry weight). Following dredging, a composite cap comprised of 15 cm sand, 15 cm gravel, and 15 cm armor stone was placed over the 0.7 hectare area (Palermo et al., 1998) to contain the residuals left behind. The sand layer included an amendment of organic carbon. The monitoring program consists of visual observation of the armor stone layer along set transects. To date, monitoring has shown the cap has maintained its integrity as a whole (BBLES, 1996).

Central Long Island Sound Disposal Site (CLIS) - Long Island, New York

The Central Long Island Sound Disposal Site (CLIS) includes several sediment disposal mounds that were capped by the USACE - New England Division. The chemical constituents associated with the disposal mounds include PCB, elevated levels of heavy metals (cadmium, copper, and zinc), oil, and grease. Cap thickness associated with each of the individual disposal mounds vary, with a mean cap thickness exceeding 20 to 41 cm. Cap components primarily consist of a coarse-screen sand mixed with calcareous shell fragments.

In 1990, 40 cores were collected in three of the mounds to monitor the effectiveness of the capping materials. Of these 40 cores, 15 were selected for chemical analyses. Results indicated no change in baseline conditions. The visual and chemical transition at the sediment/cap interface was distinct, indicating no constituent migration through the cap (Fredette et al., 1992). Even when directly in the path of Hurricane Gloria, the erosion of the CLIS caps was minor and limited to the top few centimeters; most elevation changes observed were due to consolidation, not erosion (Fredette et al., 1989). Brandes et al. (1991) state that "after 7 to 10 years, coring results indicate that the cap layers still exist at all three mounds and that they continue to isolate the contaminated dredged materials from direct contact with the water column."

Mud Dump Site - New York Bight, New York

In 1980, approximately 390,000 m^3 of silt and clay were dredged from New York Harbor by the USACE - New York District and disposed at the Mud Dump Site. The materials originated from six different projects, but primarily contained elevated concentrations of heavy metals (cadmium, copper, zinc, and lead). The disposed materials were capped with approximately 92,000 m^3 of mud, followed by 918,000 m^3 (0.9 m) of sand. In July 1983, vibracore samples were taken at the Mud Dump Site. Core samples taken from eight locations on the capped mound indicated that there was a sharp interface between the sand and the mud. Based on chemical analyses, there appeared to be little or no vertical gradient in metals concentration between the interface region and the upper portion of the sand cap. As a result, it was determined that no migration of sediments had occurred into the cap (Sumeri et al., 1991).

On May 13, 1997 "USEPA proposed to de-designate and terminate the New York Bight Dredged Material Disposal Site (also known as the Mud Dump Site) as of September 1, 1997. The Mud Dump Site was designated in 1984 for the disposal of 76.5 million m^3 of dredged material from navigational dredging and other dredging projects associated with the Port of New York and New Jersey and nearby harbors. Simultaneous with closure of the Mud Dump Site, the site and surrounding areas that have been used historically as disposal sites for dredged materials will be redesignated under 40 CFR Part 228 as the Historic Area Remediation Site (HARS). HARS will be managed to reduce impacts of historical disposal activities at the site to acceptable levels (in accordance with 40 CFR 228.11(c)). This amendment will, when finalized, identify for remediation an area in and around the Mud Dump Site which has exhibited the potential for adverse ecological impacts. The HARS will be remediated, with approximately 1 meter of (capped) clean dredged material (i.e., dredged material that meets current Category I standards for "Remediation Material," and will not cause significant undesirable effects including bioaccumulation)" (USEPA, 1997b).

Madison Metropolitan Sewerage District Lagoons - Madison, Wisconsin

The Madison Metropolitan Sewerage District Lagoons Superfund Site consists of two sludge lagoons covering an area of 57 hectares, which are located within an ecologically sensitive wetlands area. The site was placed on the National Priorities List (NPL) due to the presence of PCB in the sludge at concentrations greater than 50 mg/kg. As outlined in the March 31, 1997 Record of Decision (ROD), the final site remedy includes the segregation and in-situ containment of sludge with PCB concentrations greater than 50 mg/kg. A cover system consisting of a geotextile layer and approximately 0.3 m layer of lightweight soil is to be placed over the exposed sludge. The soil layer would be seeded to encourage appropriate vegetative growth. Sludge with PCB concentrations less than 50 mg/kg has been and would continue to be land applied (USEPA, 1997a).

Sheboygan River and Harbor - Sheboygan, Wisconsin

From November 1989 through November 1990, sediments from nine sediment deposits in the Sheboygan River were removed, placed in a Confined Treatment Facility (CTF), and capped as part of a pilot study. The cap in five of the areas consisted of a 150-mil layer of geotextile fabric, a 0.3 m layer of run-of-bank material, a second layer of geotextile fabric, a 15 to 30-cm layer of cobble, cobble-filled gabions around the perimeter of the area, and additional run-of-bank material on, between, and around the gabions located on the shoreline. Each of the areas has been "silted over" with sediment particles filling the voids between the cobbles (BBL, 1995). The deposition of sediment also has facilitated vegetative growth on top of the armored areas, which serves to further stabilize the armoring.

The capped/armored areas have been observed several times per week since completion of construction. Based on these observations, the armored caps appear to be intact as designed. The capped/armored areas have experienced extensive sedimentation or "silting over" of the cobble material. This additional layer of natural sediment further stabilized the cap by increasing the cap thickness resulting in further impediment to bioturbation and chemical migration, and facilitating vegetative growth on top of the capped/armored areas, which increases scour resistance during high-flow events and provides a root structure to further stabilize the cap system. This vegetative cover is present over most of the capped/armored surfaces.

In 1990, a bench-scale armoring study was conducted by Enseco, Inc., of Marblehead, Massachusetts. Results of the bench-scale study indicated that capping of sediment had a significant effect on reducing the PCB concentration measured in exposed aquatic organisms (BBL, 1995).

Rahway River - Linden, New Jersey

As part of a Resource Conservation and Recovery Act (RCRA) Corrective Action program at an industrial facility in Linden, New Jersey, a sediment cap was designed and installed over a 0.2-hectare area of the Rahway River. The site is located at the confluence of two major water bodies (the Arthur Kill and Rahway River). Sediment contaminants included DDT (and its metabolites) and metals. The sediment cap consists of a layer of non-woven geotextile fabric on the native sediment, overlain by 2,900 m^3 of sand filter material, a second layer of non-woven geotextile fabric, and over 1,900 m^3 of rip rap to armor the sand filter material. The sand filter layer is designed to allow groundwater release, but retard chemical release from the site to the river. In addition, a 30-cm by 46-cm rip-rap lip was constructed around the perimeter of the cap. Cap construction is complete and has received final closure approval.

Palos Verdes Shelf - Palos Verdes, California

USEPA is in the process of completing a pilot project to test the efficacy of using clean materials to cap sediments at the Palos Verdes continental shelf site in California. Approximately 12 million cy of sediment containing DDT and PCB are reportedly on the Palos Verdes shelf. Clean sediment from a dredging project in a Los Angeles port is being used to cap three 45-acre cells on the Palos Verdes shelf. The goal of the project is to test different capping thicknesses, the capping placement method, and the potential capping material. The initial capping thickness is six inches, which will be increased if the USEPA is not satisfied with the six-inch cap. The USEPA plans to evaluate the effectiveness of the cap both during and after the project (USEPA, 2000).

Pine Street Barge Canal – Burlington, Vermont

Wastewater associated with a coal gasification plant was released directly into the canal during operation. Residual oils and wood chips saturated with organic compounds contaminated the sediments in the canal and surrounding wetlands with PAHs, metals, and volatile organic compounds (VOCs) such as toluene, benzene, and xylenes. The original remedial action called for dredging of the affected areas, but local opposition to destruction of wetland habitats led to the first site in the country where a public consensus group has been used to develop and recommend a Superfund Site remedy. The final remedy recommended is in-situ capping with sand/silt over the 5 to 6 acres of affected canal sediments, and placement of a soil cap over the 2 to 3 acres of wetland area. Long-term monitoring of storm water, cap material effectiveness, and surface/groundwater chemistry is also part of the remedy established to ensure that no constituents are migrating offsite (GE, AEM, and BBL, 2000).

McCormick and Baxter (Portland Plant) – Portland, Oregon

A 0.5 mile nearshore area of the Willamette River contaminated with PAHs due to a wood treating facility has been targeted for capping. Contamination may reach depths up to 35 feet. The ROD issued for the site calls for a minimum 3 foot sand cap (armored as necessary to prevent erosion). The cap design is currently on hold awaiting the results of groundwater remediation to assure prevention of further leakage into nearshore sediment. Earliest cap placement is projected for the year 2001 (GE, AEM, and BBL, 2000).

Capping Design Considerations

Capping/armoring and in-place containment have been selected and implemented at many sites across the country. Monitoring has shown these techniques to be effective at mitigating both constituent migration and uptake by aquatic biota. This assessment is based upon site-specific monitoring, bench-scale studies, and the documented effectiveness of in-place containment at other sites. In summary, capping/armoring and in-place containment can offer several benefits, including reduction of sediment chemical bioavailability, control of releases of constituents from sediment, and establishment of conditions conducive to anaerobic biodegradation (i.e., PCB dechlorination).

At the Kalamazoo River, the cap would be designed to perform three principal functions: provide physical isolation, stabilize the sediment, and reduce PCB flux from the sediment to the water column in gaining portions of the river (areas where the river is fed by groundwater). For the cap to function over the long-term, it must be physically stable. To accomplish this, the final design could include an additional layer of armor material in high-energy sections of the river to guard the cap against high flow velocities. In addition to the potential for cap erosion, the cap material could be affected by bioturbation - the mixing of the upper bed material by benthic organisms, bottom-feeding/breeding fish such as carp, or other organisms. For the purpose of this FS it is assumed that the cap itself would have a thickness sufficient for both physical (bioturbation) and chemical isolation (where necessary). If necessary, a layer of gravel or cobble would be included to provide armoring in the free-flowing reaches and in other high-energy sections of the river. In addition, if a filter layer between adjacent materials (cap/sediment interface or cap/armor interface) were necessary, geosynthetic materials would be used.

Determination of the appropriate cap thickness depends on the physical and chemical properties of the target sediment, cap material, hydrodynamic conditions, potential bioturbation of the cap, and bearing capacity of the sediment and potential for cap consolidation. The approach for selection of specific design parameters and components for the cap would follow the in-situ cap design protocol set forth in the USEPA ARCS program *Guidance for In-Situ Subaqueous Capping of Contaminated Sediments* (Palermo et al., 1998).

Field and laboratory experience has shown that a properly designed and constructed cap will produce an effective chemical barrier. Properly designed caps act as both a filter and buffer during advection and diffusion (Palermo et al., 1999). It should be noted, however, that capping a riverine system such as Kalamazoo River could permanently destroy or significantly alter in-stream substrate and habitats and change in-stream morphology (i.e., creation of shallow areas, reduction in flood-storage, forcing riverbank and bed scour in downstream areas, etc). Should capping be chosen as the remedy, the majority of the work leading to a design would be completed during the pre-design phase using common procedures, methods, and models that are already in use. Specific components of the design would include the following:

- Evaluation of available cap material and assessment of compatibility with intended uses at the Site;
- Evaluation of the potential bioturbation on/within the cap and design for physical isolation of the sediment contaminants from aquatic biota including fish and benthos;
- Evaluation of sediment and cap material interaction, including the effect of consolidation and bearing capacity of the underlying sediment on cap stability;
- Evaluation of the potential long-term and episodic erosive forces exerted on the cap and design of an armor component to stabilize the cap, if necessary; and
- Evaluation of the chemical isolation provided by the cap in light of design objectives.

Available Materials for Capping

In a riverine setting, a multi-component cap design could be appropriate. Material for cap design falls into four general groups: 1) granular material (the cap itself); 2) stone (to serve as armor if necessary); 3) geotextiles (for a variety of barrier and filter uses, if necessary); and 4) AquaBlok™ or other manufactured products.

Locally-available sand would likely be used for the proposed cap. If the available sand sources do not contain sufficient total organic carbon (TOC) based on testing prior to placement, the sand would be amended with organic matter through mixing. Armor stone, if necessary, would be sized by the analysis of erosional forces exerted on the cap, briefly discussed below. In selecting armor stone, a secondary consideration might be its effect upon habitat. The use of geosynthetics would be considered for a filter layer between cap components or cap and sediment to minimize the potential for loss of finer materials.

The availability of certain types of the required materials (e.g., specific sizes of gravel) appears to be limited in the vicinity of the Site. Geotextiles are readily available from local suppliers.

Bioturbation

Cap design considerations would include an evaluation of the potential impact of benthic organisms and bottom feeding/breeding fish on the integrity of the cap components. In coordination with the design of other cap features, the final design would either adjust cap thickness and/or provide a layer that minimizes the extent of bioturbation to facilitate effective biological isolation of PCB. Bioturbation refers to the processing/mixing of sediments by aquatic organisms, including macroinvertebrates and fish, during burrowing, feeding, breeding, respiratory, and excremental activities. Bioturbation affects the physical and chemical processes that occur in sediments (McCall and Fisher, 1980), and may result in the vertical and horizontal movement of sediment and porewater. In most benthic environments, numbers of macroinvertebrates and rates of sediment turnover are highest in the oxygenated zone above the redox boundary, generally the top 2 to 5 cm of the sediment column (Bowsworth and Thibodeaux, 1990). Typically, the majority of bioturbation occurs to depths of 6 to 10 cm (Ford, 1962; McCall and Fisher, 1980; Karickhoff and Morris, 1985), and only occasionally occurs at greater depth. Grain size and organic content have been shown to affect habitat selection and feeding behavior of benthic organisms (USACE, 1996). The placement of sand on the bottom sediment of the Kalamazoo River may further reduce the anticipated burrowing depths of benthic invertebrates.

Sediment Bearing Capacity and Consolidation

The bearing capacity of the underlying sediments for support of the cap could be evaluated using classical bearing capacity theory (Palermo et al., 1998). The bearing capacity is applicable during construction of the cap to evaluate if the leading edge cap placement would cause unacceptably high vertical and lateral deformations of the underlying sediments, possibly causing the cap to sink below the sediments. Bearing capacity is not anticipated to be a critical issue during long-term cap performance.

Placing a new load on the sediments due to capping is expected to cause settlement of the sediment surface. Therefore, cap design should include evaluation of both stability and porewater expulsion due to consolidation of underlying sediments. Because sand would be proposed as the cap material, consolidation of the cap material itself would not be considered.

For an assessment of geotechnical compatibility of proposed capping material, a host of geotechnical data would be needed, including shear strength and consolidation. The combined use of the shear strength and consolidation testing data would provide valuable guidance in assessing potential placement rates of capping materials. The gradation and cohesive strength of the surficial in-situ sediments also would be needed to evaluate the filtering requirements for the initial layer of capping material.

Erosion Protection

The cap would be designed to withstand extreme river velocities or potential sources of turbulence, such as propeller wash. Site-specific velocity measurements taken between August 1993 and February 1994 show that the measured velocities ranged from 0.5 feet per second (fps) to 3.4 fps with an average value of 1.7 fps. Methods for predicting navigation-induced erosive forces were previously developed for design of riverbank protection and navigation structures. The USEPA capping guidance document provides means for determining armor stone size based upon computed navigational induced stresses and river velocities generated by external events (e.g., floods).

Chemical Isolation

The USEPA developed a model to predict the long-term movement of chemicals into or through caps due to advection and diffusive processes. The USEPA states: "This model has been developed based on accepted scientific principles and observed diffusive behavior in laboratory studies (Bosworth and Thibodeaux, 1990; Thoma et al., 1993; Myers et al., 1996)" (USEPA, 1998). Among the factors considered by the model are cap thickness, physical properties of the sediment and cap material, chemical concentrations in the sediment, and other parameters. The results generated through use of this model include diffusive and advective flux rates, breakthrough times and porewater concentrations at breakthrough.

The above design process would result in a Site-specific cap design for various reaches of the Kalamazoo River. It is anticipated that the conceptual cap design discussed in the FS would be refined during final design should this alternative be chosen as a remedy. Appropriate data would be collected to complete the design. A potential list of required information is provided below:

Sediment physical properties

- Sediment consolidation tests (ASTM D2435)
- Vane Shear tests (ASTM D2573)
- Grain Size Analysis (ASTM D422 and ASTM D1140)
- Specific Gravity (ASTM D854)
- Atterberg Limits (ASTM D4318)
- Water Content (ASTM D2216)
- Bulk Density (USACE EM-1110-2-1906 Volumetric Method)
- Organic Content (ASTM D2974)

Sediment chemical properties

- Boundary PCB concentrations in sediment
- Sediment porewater PCB concentrations
- Sediment TOC concentrations

In addition, the groundwater seepage flux to the overlying surface water would need to be determined at gaining portions of the river system. This could be directly measured using seepage meters at selected locations of the Kalamazoo River. While the majority of data needed are available, some information such as groundwater seepage rates, sediment porewater PCB concentrations, sediment consolidation properties, shear strength values, etc. would need to be collected.

When complete, the data would provide quantitative information useful in evaluating the thickness and composition of the cap, thickness of armor layer (if necessary) and relative potential for scour, and geotechnical stability of the cap.

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Appendix D

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engineers & scientists

Site Profiles of Sediment Dredging Projects

Appendix D: Site Profiles of Sediment Dredging Projects

1.0 General

A review of environmental dredging projects found that environmental dredging presents inherent limitations and uncertainties in meeting project-specific objectives and overall effectiveness. These limitations and uncertainties influence dredging projects in site-specific ways. Some site-specific challenges and potentially limiting factors of environmental dredging projects include dredging technology, physical properties of the sediments, bottom conditions, dredging surface area, depth of sediments targeted for removal, hydrodynamic conditions, chemical constituent concentrations, and project remedial action objectives or "cleanup goals." For many environmental dredging projects, the major challenges include controlled sediment removal to minimize mixing with underlying material or surrounding sediment, mitigation of resuspended sediment and resettlement of sediment, and minimization of areas that the dredge misses. The extent of the effect of these limitations varies with the physical nature of the sediments, other site conditions, operational control, and precision of the dredging equipment and operator.

Such limitations and uncertainties result from a variety of conditions encountered in a typical river or harbor system. For instance, the presence of cobbles, boulders, or other debris on the waterway bottom may affect dredging effectiveness. The condition of materials (i.e., an uneven waterway bottom) or the ability to effectively overexcavate the target materials may restrict dredge movement and removal activities, thus making efficient sediment removal difficult. Sediment that becomes resuspended by removal operations will resettle and/or possibly mix with other "cleaner" sediments nearby or will migrate outside the limits of the targeted sediments. In addition, precise control of sediment removal operations is challenging, since removal typically occurs under water.

The above factors contribute to the finding that low polychlorinated biphenyl (PCB) cleanup levels (e.g., in the range of 10 parts per million [ppm] or lower) generally are not consistently achievable via dredging. Data collected during and immediately after dredging activities at several PCB sites have indicated that even higher PCB cleanup levels may likewise be unattainable, depending on site-specific issues. Additionally, the U. S. Army Corps of Engineers (USACE) has stated that "no existing dredge type is capable of dredging a thin surficial layer of contaminated material without leaving behind a portion of that layer and/or mixing a portion of the surficial layer with underlying clean sediment" (Palermo, 1991). Therefore, even though a dredge may be capable of removing substantial volumes of sediment and associated PCB mass, the sediments that the dredge is not capable of removing, which eventually settle as a result of resuspension, or those the dredge misses or mixes with underlying sediment not targeted for removal, will remain.

This appendix compiles profiles of sites nationwide illustrating environmental dredging projects. While these sites represent varying hydrologic and sediment environments, the information presented is useful in evaluating and understanding general technical limitations and uncertainties inherently associated with environmental dredging projects. The sites profiled are:

- Cumberland Bay (New York);
- Lower Fox River (Wisconsin);
- Grasse River (New York);
- St. Lawrence River (New York);
- Manistique River and Harbor (Michigan);
- Sheboygan River and Harbor (Wisconsin);
- New Bedford Harbor (Massachusetts);
- Ruck Pond (Wisconsin);
- Waukegan Harbor (Illinois);
- Ford Monroe-River Raisin (Michigan);
- Shiawassee River (Michigan);
- Willamette River (Oregon);
- Duwamish Waterway (Washington);
- Marathon Battery (New York);
- United Heckathorn (California);
- Bayou Bonfouca (Louisiana);
- Black River (Ohio);
- LTV Steel (Indiana);
- Commencement Bay (Washington); and
- Lake Järnsjön (Sweden).

2.0 Site Profiles

Although dredging has been used extensively for river and harbor maintenance activities throughout the United States, dredging of PCB-containing sediments where removal efficiency was documented through post-removal PCB sampling has been limited. Several sites where such information is available are discussed below.

2.1 Cumberland Bay, New York

Between July 1999 and October 2000, over 160,000 cy of material was hydraulically dredged from the Cumberland Bay - Wilcox Dock Site, located in Plattsburgh, New York. The site consists of a 34-acre sludge bed which is composed of wood pulp, wood chip debris, and other processing wastes from local wood preserving industries. PCB concentrations up to 1,850 ppm were detected in sludge samples (NYSDEC, 1997).

The goal of the remedial action was to remove the entire sludge bed; no PCB cleanup goals were set (NYSDEC, 1997). In the Contract Documents, the volume estimated to be removed was 131,000 cy (116,000 cy from the sludge bed and 15,000 cy from the shoreline) (NYSDEC, 1998). At the end of 1999, 158,250 cy of material (141,000 cy of sludge from the sludge bed and 17,250 cy of soil from the shoreline) had been removed (NYSDEC, 1999b).

Dredged slurry was pumped from the Bay to an on-shore treatment facility. The slurry was dewatered using plate and frame presses and the dewatered sludge was shipped to an off-site landfill for disposal. The decant water was treated and returned to the Bay.

Dredging was originally scheduled to begin on June 1, 1999 and be completed by November 1, 2000 (NYSDEC, 1998), based on a 12-hour work day. In mid-August 1999, the dredging began on a 24 hours a day, 6 days a week schedule in order to expedite the project. Sevenson Environmental, the dredging contractors, expected that the dredging would be completed in the fall of 1999 based on the new schedule (Lanphear, 1999).

Sheetpiling and silt curtains were placed around the perimeter of the sludge bed in order to limit the spread of resuspended materials. The NYSDEC performed water column monitoring around the perimeter of the sludge bed. Dredging operations were to be shut down if monitoring showed that an unsatisfactory level of suspended material was flowing into the rest of the Bay.

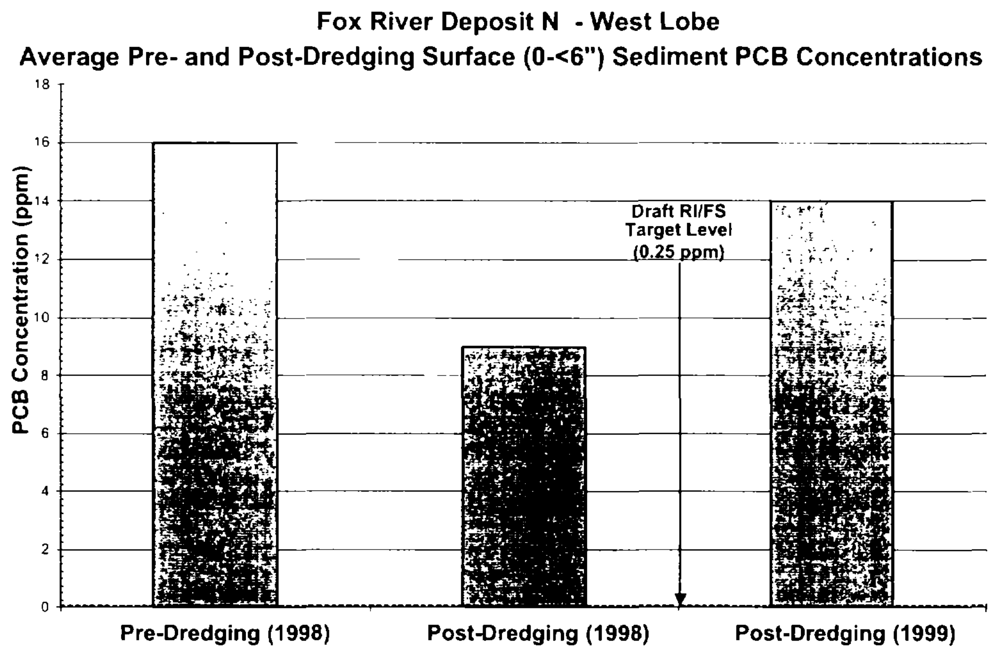
The estimated cost for the sludge bed removal was originally $23 million (NYSDEC, 1999a). To date, the final costs have not been released by the NYSDEC.

2.2 Lower Fox River, Wisconsin

Deposit N Removal Operations

Sediment Data:

Approximately 8,200 cy of sediment was removed from a 3-acre area at Deposit N [Note: This volume includes 1,000 cy of sediment from a nearby sediment area (Deposit O)] in the Fox River located near Little Chute and Kimberly, Wisconsin beginning in November 1998 as part of a demonstration project managed and executed by the Wisconsin Department of Natural Resources (WDNR). The project specification for the demonstration project was to remove the majority of the contaminated sediments from the 3-acre area deposit efficiently and in a cost-effective manner, realizing that a thin layer of sediment would be left behind due to the presence of bedrock and the limitations of dredging (Foth & Van Dyke, 2000). The sediment volume targeted for removal was approximately 65% of the 11,000 cy present in Deposit N (Foth & Van Dyke, 2000). Two rounds of dredging were conducted at Deposit N, the first during November and December 1998 and the second between August and October 1999, since dredging could not be completed in 1998. Subsequent to the removal of approximately 7,200 cy of sediment from Deposit N, funds and good weather allowed the removal of approximately 1,000 cy from Deposit O in October and November 1999. The overall cost of the demonstration project was $4.3 million, which equates to unit cost of $525 per cy (Foth & Van Dyke, 2000).



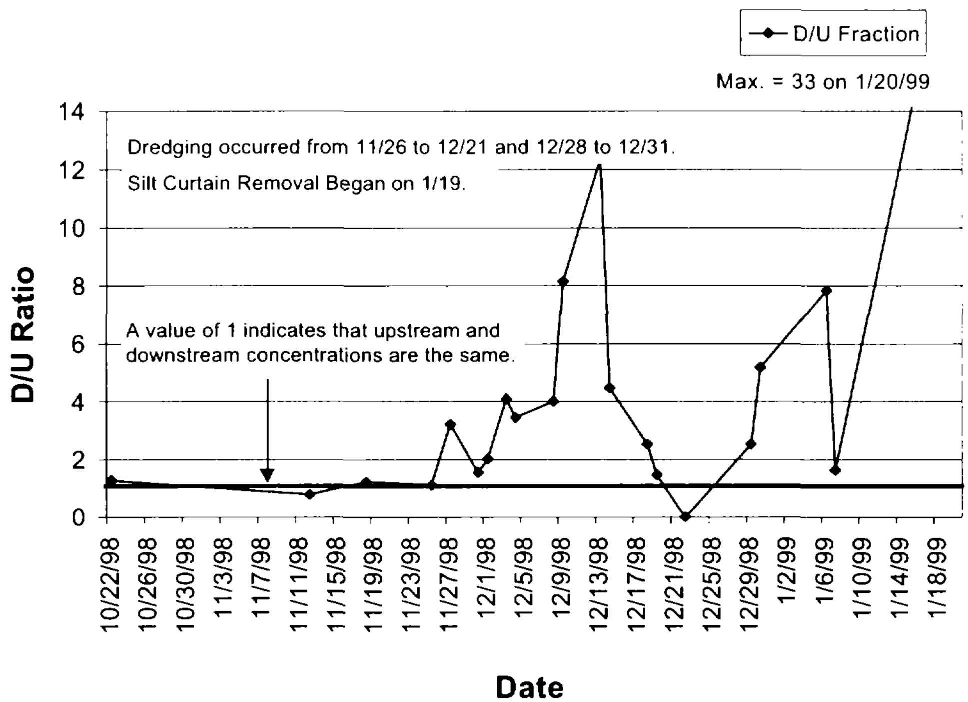
As shown on the above figure, the pre-dredge average surface sediment PCB concentration for Deposit N in 1998, was 16 ppm (BBL, 2000). The 1998 post-dredge average surface PCB concentration was calculated by BBL to be approximately 9 ppm. The 1999 post-dredge average surface PCB concentration is 14 ppm as reported by Foth & Vandyke (2000). Independent calculations by BBL result in a 1999 post-dredge average surface PCB level of 21 ppm.

The pre-dredging average sediment thickness was 2 to 3 feet over fractured bedrock in water depths of approximately 8 feet (Foth & VanDyke, 2000). Shallow bedrock at the site prevented over cutting beneath the sediment and resulted in residual sediment left behind. Post-dredge 1999 probing data collected from the west lobe of Deposit N showed that an average of 5 inches of PCB-containing sediment remained, with as much as 15 inches remaining in one portion of the deposit.

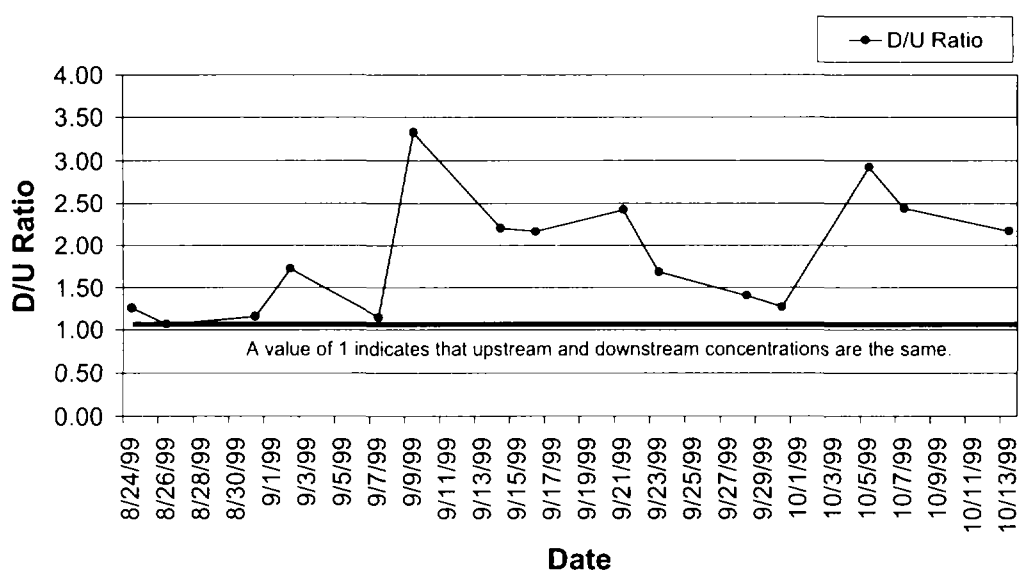
Resuspension Data:

Two rounds of dredging were conducted at Deposit N: the first during November and December 1998, and the second between August and October 1999. In 1998, the dredging area was surrounded by a silt containment system including an 80-mil high density polyethylene (HDPE) flexible plastic barrier and a silt curtain. In addition, two deflection barriers were used to direct water around the local paper mill water intake. No turbidity barrier was used during the 1999 dredging. However, a silt curtain was placed approximately 150 feet or less downstream of the dredge (Foth & VanDyke, 2000). Generally speaking, data from both Deposit N dredging events indicate higher PCB concentrations downstream of the dredging site during dredging, while pre-dredging upstream and downstream PCB concentrations are similar.

1998 Water Column Data - Ratio of Downstream To Upstream Total PCB Concentration



1999 Water Column Data - Ratio of Downstream To Upstream Total PCB Concentrations During Dredging



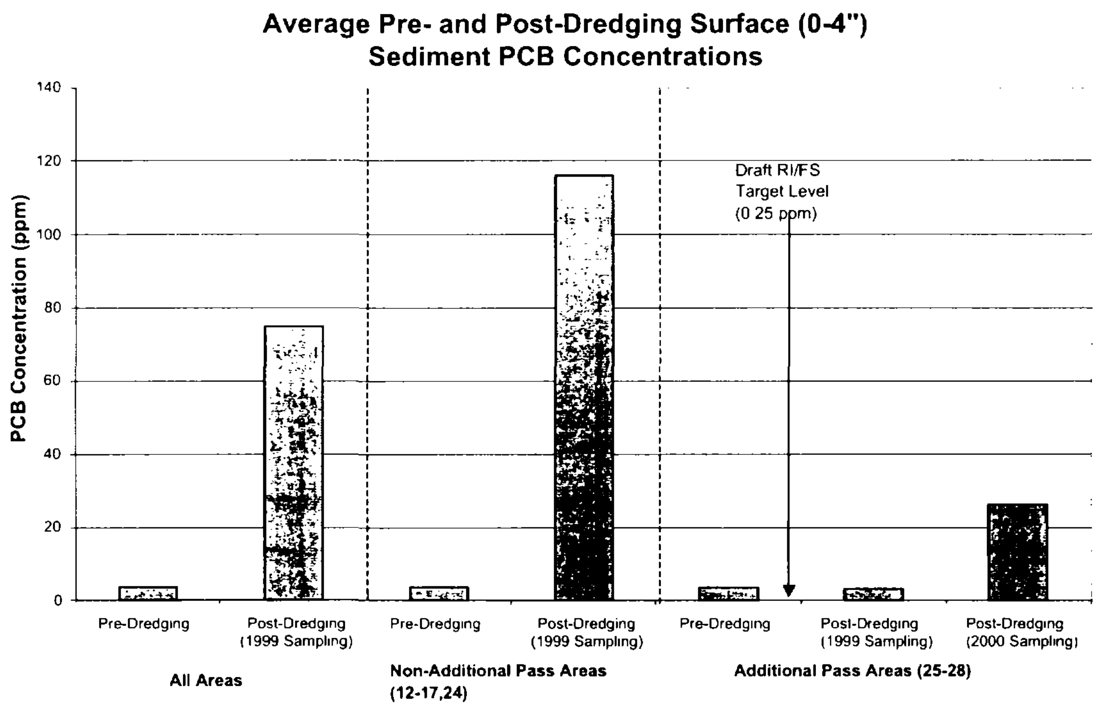
In 1998, the pre-dredging PCB concentrations in upstream and downstream samples were similar, averaging 15 nanograms per liter (ng/L) upstream and 15 ng/L downstream. As indicated in the above figures, evaluating the changes in the downstream to upstream PCB concentration (D/U ratio) indicates that downstream PCB concentrations during dredging exceeded upstream concentrations in both 1998 (by a factor of 1.5 to 12.4) and 1999 (by a factor of 1.1 to 3.3) (BBL, 2000). This trend was not evident in the pre-dredging samples. On average, downstream PCB concentrations were 4.3 times higher than upstream PCB concentrations during 1998 dredging and 1.9 times higher during 1999 dredging (BBL, 2000).

SMU 56/57 Removal Operations

Sediment Data:

Sediment Management Unit (SMU) 56/57 is a 9-acre area located along the west bank of the Fox River in Green Bay, Wisconsin. Of the 117,000 cy of sediment in SMU 56/57 with PCB concentrations greater than 1 ppm, 80,000 cy were targeted for removal. In August 1999, dredging began and removed approximately 31,500 cy of sediment (mainly from eleven 100-foot by 100-foot subunits) using a hydraulic horizontal auger dredge. The goal of this demonstration project was to understand the implementability, effectiveness, and cost of a large-scale sediment removal project. Dredging continued through mid-October 1999, when a review of survey information indicated that the dredging process was leaving a very uneven surface on the river bottom. The WDNR directed the contractors to stop disturbing new areas and instead redredge areas that had already been disturbed. In December 1999, additional dredging passes intended to reach target elevations were performed on small (30-foot by 30-foot) sections of four subunits. On average, the additional dredge passes targeted the removal of six inches of sediment.

All of the funds allotted for this demonstration project have been expended with only one-third of the sediment volume removed. The project cost incurred thus far is approximately $9 million, which equates to a unit cost of approximately $317 per cy (note this cost does not include typical disposal fees, as these services were provided through use of existing landfill space owned by one of the responsible parties at the site). Dredging began at SMU 56/57 on August 26, 2000 to accomplish additional remediation not completed in the demonstration project on this river, meaning that Fort James has agreed to attain a specific target of [0.25 ppm] PCB concentration" (WDNR, 2000). Approximately 50,000 cy of sediment is expected to be dredged in Phase I and II. An engineering evaluation will be performed at the end of Phase I (fall 2000) to determine if Phase II can be completed before the onset of winter forces a shutdown of remedial efforts. "Phase II will be dredged to the extent that the cleanup objective can be met and stable slopes established" (WDNR, 2000).



Pre- and post-dredging PCB data were collected by BBL and Montgomery Watson. Pre-dredging surface PCB concentrations collected in the eleven dredged subunits averaged 3.6 ppm and ranged from 1.7 to 5.9 ppm (BBL, 2000). Two rounds of post-dredging sampling were conducted: the initial round in December 1999/January 2000 immediately following dredging, and the second round in February 2000. The average surface PCB concentration in the eleven subunits increased to 75 ppm (range: 0.03 to 280 ppm) based on the December 1999/January 2000 sampling event.

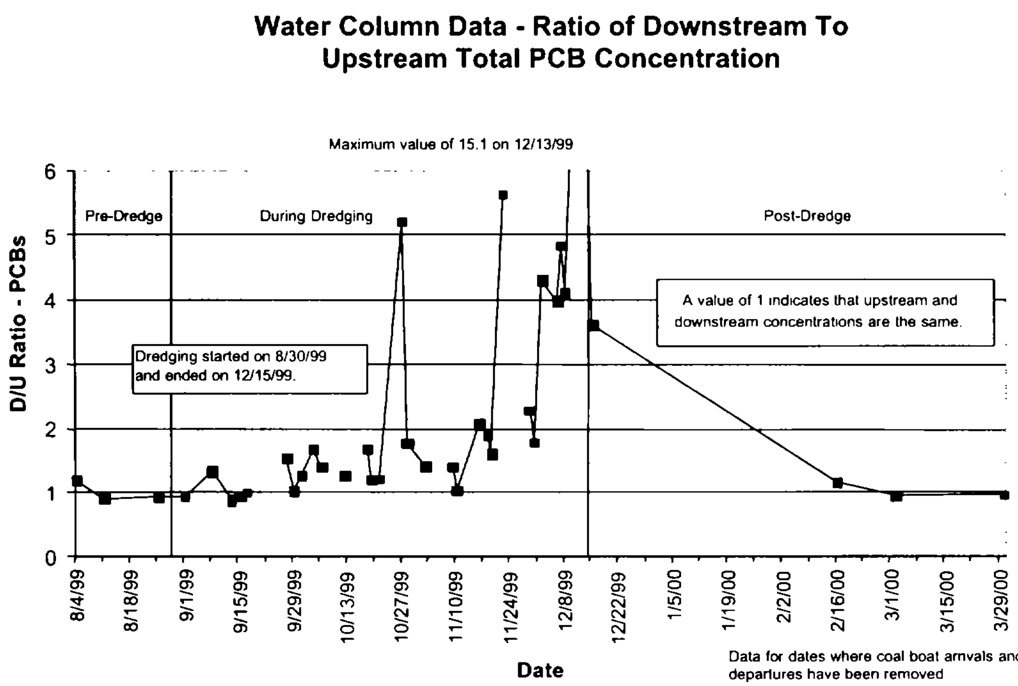
The pre-dredge surface PCB concentration in those seven subunits that did not receive a cleanup pass was 3.7 ppm (range: 1.7 to 5.9 ppm). Results of the December 1999/January 2000 sampling indicate that average surface PCB concentration in these seven subunits to be 116 ppm (range: 32 to 280 ppm). Only three of these seven subunits were sampled in February 2000 and the resulting average surface PCB concentration was 65 ppm (range: 40 to 110 ppm) (BBL, 2000). Surface sediment concentrations pre-, during- and post-dredging are shown in the above figure.

In those four subunits where an additional "cleanup" pass was performed, pre-dredge surface PCB concentrations were 3.5 ppm (range: 2.7 to 4.7 ppm). In December 1999/January 2000 surface PCB levels decreased slightly to an average of 3.2 ppm (range: 0.03 to 10.8 ppm), while the February 2000 sample results indicated an increase in PCB surface concentration to 26 ppm (range: 16 to 34 ppm) in these four subunits (BBL, 2000).

Dredged sediments were dewatered and disposed (as an in-kind service) at a landfill operated by the Fort James Corporation.

Resuspension Data:

The SMU 56/57 dredge area was enclosed by a silt curtain. PCB levels in the water column were monitored pre-, during-, and post-dredging. Generally speaking, PCB concentrations were higher downstream of the removal area than upstream during dredging.

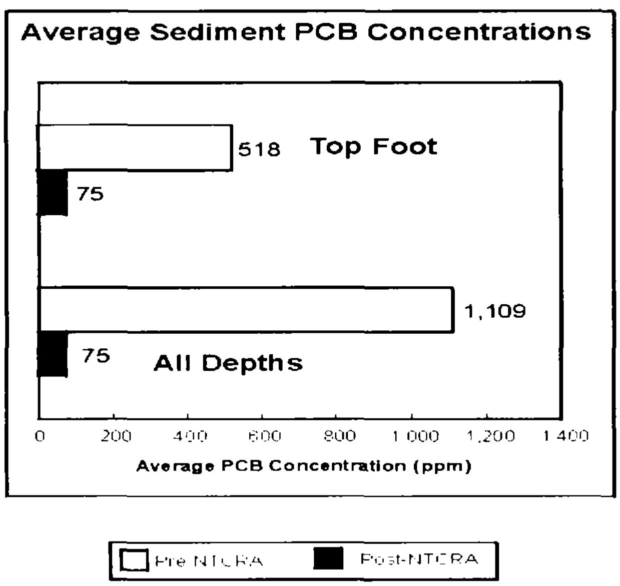


As shown in the adjacent figure, water column PCB data was analyzed through an evaluation of the downstream to upstream PCB concentration (D/U) ratio. Samples collected during coal boat delivery times were removed to eliminate downstream bias, which may be caused by resuspension due to coal boat travel. The pre-dredging upstream and downstream average PCB concentrations were 53 ng/L and 52 ng/L, respectively (resulting in a D/U ratio of approximately 1.0). The overall during-dredging D/U ratio indicates that, on average, PCB concentration were higher in downstream samples by 2.6 times after removing sampling dates that coincided with coal boat arrivals and departures.

2.3 Grasse River, New York

Between July and September 1995, Alcoa, Inc. removed approximately 3,000 cy of sediment and boulders/debris from two areas of the Grasse River due to elevated levels of PCB (up to 11,000 ppm). The removal areas covered approximately 1 acre of the Grasse River (i.e., a river area and adjacent outfall structure). The goal of the removal action was to remove all sediment within these areas to the extent practicable. Nearly 400 cy of boulders were removed from a "boulder zone" with a mechanical long-stick excavator (with a specialized perforated bucket) mounted on a barge. The sediments were removed using a horizontal auger hydraulic dredge. Sediments were dewatered and disposed with the boulders and debris in an on-site landfill (BBL, 1995c). Sediments within the outfall structure were removed using small manually directed plain-suction hydraulic hoses.

Sediment Data:



As shown on the figure at left, pre-removal PCB surficial sediment concentrations (i.e., top 12 inches in this case) averaged 518 ppm (ranging from 12 to 1,780 ppm). After hydraulic dredging was completed in an effort to remove all sediment, an average sediment depth of 4 inches (up to a maximum of 14 inches) remained even after multiple dredge passes. Based on these results, the U.S. Environmental Protection Agency (USEPA) and its representatives, Alcoa, and the contractors determined that sediment had been removed to the extent practicable (BBL, 1995c). Conditions such as the rocky nature of the river bottom and the presence of hardpan reduced the dredge's effectiveness in removing sediment. It was estimated that approximately 84% of the sediments were removed (along with 27% of the PCB mass in the lower Grasse River). Following removal, residual (surficial) PCB concentrations averaged 75 ppm (ranging from 1.1 to 260 ppm). Moreover, at 30% of post-removal sample locations, residual surface sediment PCB concentrations increased relative to pre-removal concentrations (BBL, 1995c). Even in the outfall structure, where operators were able to manually direct vacuum hoses to remove sediment, surface sediment remained with PCB concentrations of 108 ppm (388 ppm PCB in surface sediment before removal).

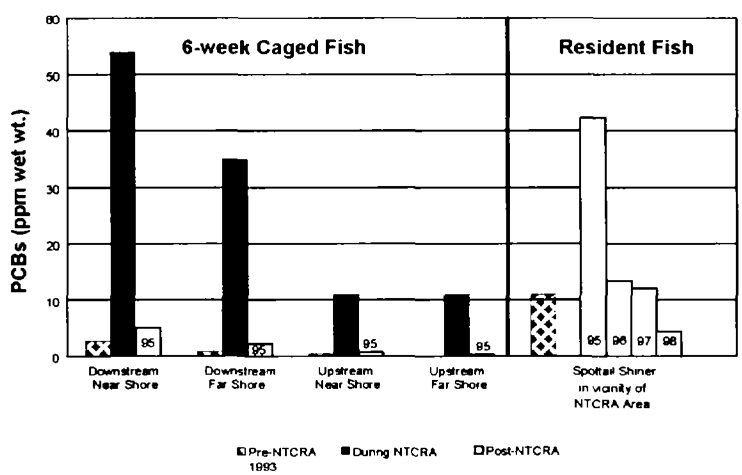
Overall, the dredging activities were completed within 3.5 months for a cost of approximately $4.9 million, with a unit cost of $1,670 per cy. This cost included investigative efforts, engineering and reporting, actual construction activities, transport and disposal, and monitoring.

Water Data:

During removal activities, a triple-tiered silt curtain system was used in an attempt to contain suspended PCB-containing sediments. The curtains were quite effective in containing suspended sediments, with only one action level exceeded for total suspended solids (TSS) and turbidity. However, elevated PCB water column concentrations were observed; that is, PCB were present in 88% of the samples collected at a location 2,300 feet downstream of the removal area, while PCB were detected only once at the upstream location. Also, two of the downstream fixed-station filtered samples had quantifiable PCB levels, whereas quantifiable levels were never observed at this location in the pre-removal monitoring.

Fish Data:

In addition to water column PCB level increases during removal, increases in fish levels also were noted during removal. The figure to the right shows both caged fish and resident spottail shiner data before, during, and after removal. Although limited data are available before removal, it is obvious that sediment removal increased PCB levels in fish during removal, and levels remained elevated for several years following removal.



Other resident fish (i.e., brown bullhead and smallmouth bass) also were collected and analyzed for PCB as part of pre- and post-removal monitoring (through 1998) of the Grasse River project. Review of the post-removal monitoring results reveal that there was generally no reduction in potential long-term risks to human health and the environment as a result of these dredging activities. For example, resident fish collected in 1995 immediately following removal exhibited an increase in PCB concentrations. PCB concentrations in resident smallmouth bass and brown bullhead samples collected prior to the removal activities are similar to those collected in 1997 and increased slightly in 1998. Overall, the apparent negative effect of the removal was greater for smallmouth bass than for brown bullhead and was most significant for spottail shiners, with the most significant differences observed in the vicinity of the removal area.

2.4 St. Lawrence River, New York

Between May 8 and December 22. 1995, General Motors (GM) removed approximately 13,250 cy of PCB sediment and associated boulders/cobbles from an approximate 11-acre area of the St. Lawrence River. These materials were dewatered and stockpiled at the GM Powertrain facility for subsequent off-site disposal.

The USEPA selected a 1 ppm sediment cleanup goal in the St. Lawrence River because it believed it was achievable and provided an acceptable measure of human health protection. In doing so, the USEPA believed it had balanced its desire for a very low cleanup level to minimize residual risk with the constraints posed by the limitations of dredging as a means of removing sediment (in Turtle Creek, a tributary to the St. Lawrence River, an applicable or relevant and appropriate (ARAR) cleanup level of 0.1 ppm was set). However, the USEPA recognized that technical limitations may preclude removal of sediments to this level (USEPA, 1990).

After efforts to utilize a silt curtain containment system failed (due to excessive water velocities), a sheetpile wall was installed around the removal area as a resuspension containment measure. Prior to sediment removal, the initial footprint of the sheetpile wall was modified to exclude a cobble and boulder zone. It was agreed by the USEPA and GM that the removal of sediment from this area was technically impractical because of large boulders and the potential for slope failures. Within the removal area, boulders and debris were removed mechanically prior to hydraulic dredging.

Total costs for the project were approximately $10 million resulting in an approximate cost of $725 per cy removed.

Sediment Data:

Pre-removal surficial sediment PCB concentrations ranged from non-detect to 8,800 ppm (average of 548 ppm) within quadrants 1 to 6.

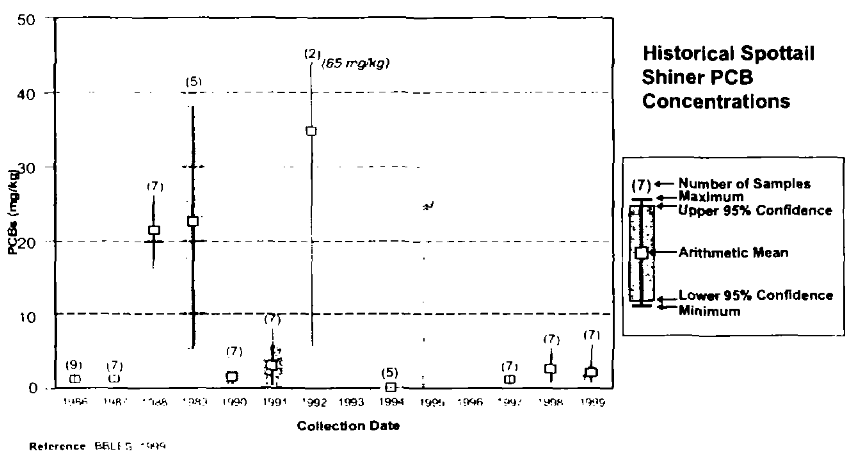
Even after significant passes with a hydraulic dredge were performed (up to 15 to 30 passes in some areas), residual surface sediment in all six removal quadrants remained above the cleanup goal of 1 ppm, with an overall average PCB-concentration of 9.2 ppm (average PCB concentrations were up to 27 ppm in one quadrant). The USEPA determined that sediments were removed to the maximum extent possible and "that installation of a cap over Quadrant 3, effectively isolating this area from the rest of the river, was the only remaining technically practicable remedial alternative." This area was subsequently capped with a multi-layer granular cover (BBLES, 1996).

Water Data:

Early on in the sediment removal process, turbidity action levels were exceeded due to turbid water escaping over the top of low sheetpiling sheets. The low sheets were installed according to the design and assured stability of the containment system during storms and high waves from passing ships. To compensate for the low sheets, the contractor installed filter fabric over the low sheets and installed short steel sheets over some of the low sheetpiles. At one point during sediment removal activities, elevated water column turbidity and PCB levels were reported outside of the sheetpile wall. Due to the high concentrations, a silt curtain was installed along the inside of the sheetpile wall. PCB were also released via air as PCB were detected at levels exceeding the project action level at the closest downwind sample location.

Fish Data:

The figure below shows total PCB concentrations in spottail shiner (the only species monitored) whole-body composite samples collected from the GM site. PCB levels may have decreased since the late 1980s, but comparison of the pre- and post-remediation data are complicated by factors such as fish sizes, lipid contents, species, mobility, and uncertainties about sampling locations (especially the 1988-89 and 1992 data relative to all other years). Previous sampling locations are important for data comparability over time. Note that remediation occurred in 1995.



The annual monitoring reports describe an anomaly to the apparent general downward trend since the late 1980s: two spottail shiner samples collected by New York State Department of Environmental Protection (NYSDEC) in 1992. The wide difference in concentrations for these two samples (total PCB concentrations of 5.7 ppm and 65 ppm) is difficult to explain. Similar variability, although not as great, is also evident in the data collected by the Ontario Ministry of the Environment (OME) in 1989. The variability of the data may be due to several factors, including differences in sampling locations, fish lengths and sizes, fish lipid content, or species mobility. In fact, discussions with both

NYSDEC and OME regarding sampling locations indicate that the specific sampling locations cannot be determined. This is extremely important given the relative size of the St. Lawrence River (about 2,000 feet wide, with average flow of 250,000 cubic feet per second [cfs]) compared to the area dredged (about 200 feet wide in an embayment). Post-dredging sampling locations are well documented, but without pre-dredging location details, one cannot consider the data truly comparable. Regardless, the variability of the data precludes a more detailed evaluation and interpretation of the overall spottail shiner data. As such, the monitoring reports conclude that the significance of the 1997, 1998, and 1999 PCB data, and any apparent trends, will need to be more thoroughly evaluated following the collection of additional data over the next several years.

2.5 Manistique River and Harbor, Michigan

At the Manistique River and Harbor site in Michigan, dredging has been performed by the USEPA in three areas (the North Bay, an area in the River, and the Harbor) to remove PCB sediments. Dredging at the site has been performed using a combination of diver-assisted and hydraulic cutterhead dredging. The USEPA's goal is to achieve a PCB concentration of 10 ppm at all depths in sediments.

Through the end of 1999, according to the USEPA, a total of less than 100,000 cy of sediment has been dredged and 41,800 tons of dewatered sediments have been shipped to off-site landfills for disposal. The table below summarizes the volumes removed by year.

Year	Volume Removed (cy)	Tons Disposed
1995	10,000 (2)	1,200 (2)
1996	12,500 (2)	2,100 (2)
1997	62,000 (3)	12,000 (3)
1998	31,200 (4)	12,600 (4)
1999	25,000 (5)	13,900 (5)
TOTAL	97,000	41,800

Notes:

1. **The volumes are based upon USEPA Pollution Reports (POLREP); volume to date modified by EPA in 1999 to 72,000 cy through 1998.**
2. **(2) indicates quantities removed from Area B, POLREP #15 and #20**
3. **(3) indicates quantities removed from Areas C and D, POLREP #40**
4. **(4) indicates quantities removed from Area D, POLREP #56**
5. **(5) indicates quantities removed from Areas B and D, POLREP #70**

As of August 2000, the cost for the project is over $42 million (Nied, 2000). The original budget in 1995 was $15 million.

Initially, the USEPA expected the dredging to be completed by the end of 1997. Currently, the USEPA estimates that dredging will be completed by the end of 2000.

Sediment Data:

North Bay (Area B)

Pre-removal surficial sediment PCB concentrations in the North Bay ranged from non-detect to 62 ppm (average of 8.8 ppm) using data collected in 1995.

The USEPA originally dredged the North Bay in 1995 and 1996. These activities were initially performed using diver-assisted dredging to remove sediment along with a layer of wood chips. Subsequent removal was then accomplished using a horizontal auger cutterhead dredge. In September 1996, the USEPA declared that dredging operations were completed in the North Bay (Nied, 1996a). Post-dredging sampling of the North Bay by the USEPA in the fall of 1996 revealed that sediment with PCB concentrations greater than 10 ppm remained. In response, the USEPA placed washed gravel in the North Bay in October 1996 to "improve the river bottom in this area as habitat for aquatic species as well as enhance containment of the contaminated residuals which could not be cost effectively recovered from beneath the debris layer during dredging" (Nied, 1996b).

In October 1998, BBL collected five sediment cores in the North Bay to confirm whether the USEPA had reached the 10 ppm PCB cleanup level. PCB concentrations in surficial (0-3 inches) sediment samples ranged from 1.3 to 1,300 ppm, with two of the five detections being greater than 10 ppm, and an overall arithmetic average of 270 ppm. Some of the subsurface intervals sampled also had PCB concentrations greater than 10 ppm. In April 1999, prior to dredging, the USEPA collected five cores in the North Bay. PCB concentrations in the surficial samples (0- to 1-foot) ranged from 16 to 116 ppm, and averaged 48 ppm. Based on the results of these sampling efforts, the USEPA decided to conduct additional dredging in the North Bay, which was conducted in May and June 1999.

After the additional dredging had ceased for the season in 1999, BBL collected nine sediment core samples from the North Bay. In the surficial interval (0-3 inches), PCB concentrations ranged from 0.25 to 15 ppm. One sample had a PCB concentration greater than 10 ppm. Six out of 13 subsurface (deeper than 3 inches) samples had PCB concentrations greater than 10 ppm, with a maximum PCB concentration of 620 ppm.

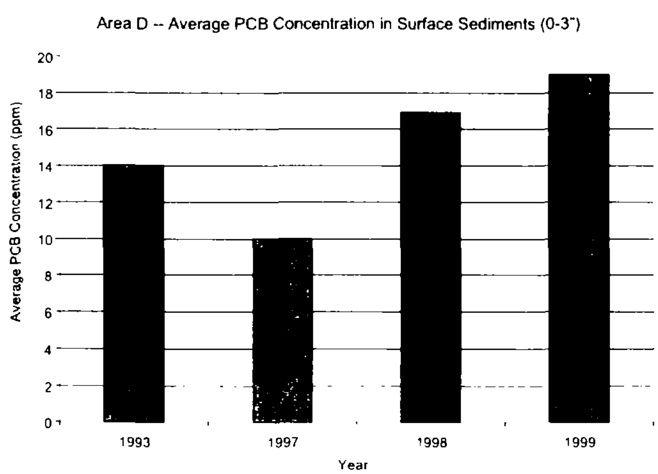
River Area (Area C)

In 1993, an interim geomembrane cap was installed as a temporary measure near an outfall. In 1997, the temporary cap was removed and the sediment was dredged. Sediment PCB concentrations were determined using immunoassay tests to assess whether the clean up goal of 10 ppm was reached. The data document that sediment PCB concentrations remained above 10 ppm. In fact over 20 percent of the samples showed that sediment above 50 ppm was left behind.

Harbor (Area D)

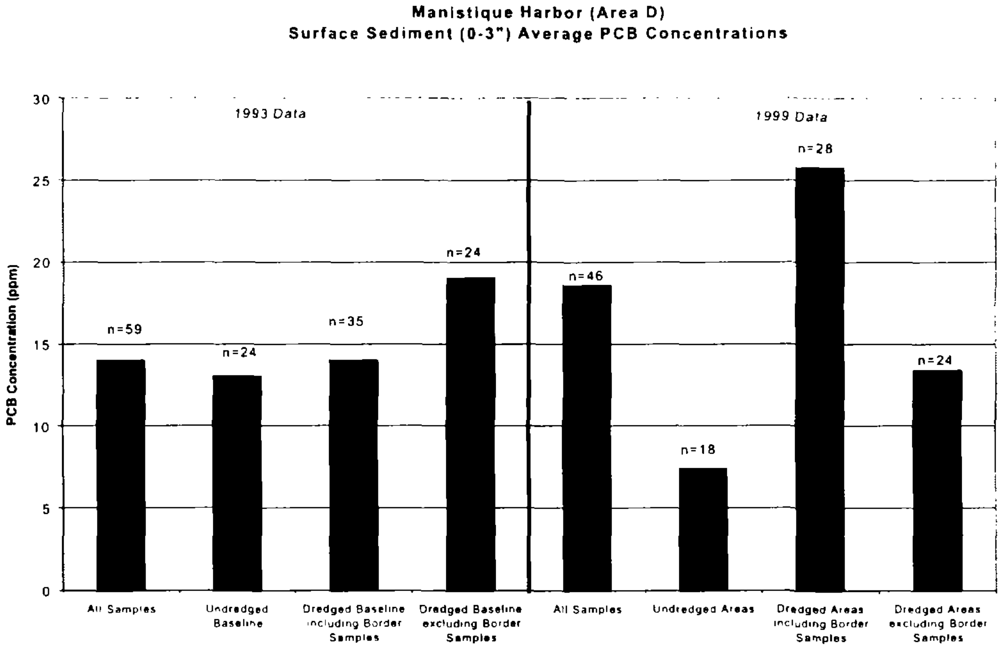
Pre-removal surficial sediment (0-3 inches) PCB concentrations in the Harbor ranged from non-detect to 90 ppm (average of 14 ppm) using data collected during the Engineering Evaluation/Cost Analysis (EE/CA) (BBL, 1994).

After the USEPA completed its dredging activities in 1997, 1998, and 1999, BBL collected between 24 and 46 core samples per year within the harbor. In all years, the samples were distributed throughout the harbor area without bias toward dredged or undredged areas. The average surface sediment PCB data is summarized in the graph below.



In addition, data from 1993 were compared to data from 1999 to determine whether there was any difference between areas which were dredged and those which were not dredged. The delineation of areas dredged (as provided by the USEPA) was overlaid with the sampling locations in 1993 and 1999 to categorize locations as either within or outside dredged areas.

Given potential mapping inaccuracies, it is possible that some sample locations may be interpretable either way (hereinafter called border samples). Using best judgement, the border samples would be considered within the dredged areas. However, for completeness, both scenarios have the average surface sediment concentrations plotted below.



[Source: BBL, 2000a]

The figure shows that while the average PCB concentrations in undredged areas in 1999 was roughly two-fold lower than in 1993, this was not the case in dredged areas. The apparent decline in undredged areas may be evidence of natural recovery.

In addition to sampling by BBL, the USEPA conducted pre-dredging sample collection in the Harbor in 1998 and 1999. In 1998, the USEPA collected 112 samples in the Harbor, and PCB surface concentrations ranged from non-detect to 1,250 ppm and averaged 16 ppm. In 1999, the USEPA collected 124 cores in the Harbor. PCB concentrations in the surficial (0- to 1-foot) sediments ranged from non-detect to 1,096 ppm and averaged 30 ppm. The average concentration both years was greater than 10 ppm and increased from 1998 to 1999, generally consistent with BBL data.

The USEPA continued to have difficulties achieving the 10 ppm cleanup goal in the Harbor. At the end of the 1999 dredging season, the USEPA collected sediment samples in the Harbor which showed an average PCB concentration greater than 10 ppm. In the 151 grab samples collected by the USEPA, PCB concentrations ranged from non-detect to 340 ppm and averaged 20 ppm at the surface (compared to 19 ppm average using BBL data). At the time of submission of the draft document, USEPA has recently announced that sampling has shown remaining PCB levels averaging 9.8 mg/kg. This appendix will be updated with those and other monitoring results in the future.

Water Data:

PCB data are available for surface water samples from the Manistique River and Harbor Site from the early 1980s to 1998. In the early 1980s, Marti and Armstrong (1990) collected five surface water samples from the mouth of the River, and in April-May 1994, the USEPA collected three surface water samples at the site as part of the Lake Michigan Mass Balance Study (LMMBS). These sample results are presented below:

Water Column Total PCB Concentrations (ppb)				
Sampling	**Range**	**Mean**	**No. of Samples**	**Reference**
Early 1980s	0.007 - 0.043	0.024 ± 0.015	5	Marti and Armstrong,1990
April/May 1994	0.0002 - 0.0021	0.0009	3	USEPA; LMMBS
1995	ND – 0.49	0.10	102	USEPA
1996	ND – 3.5	0.62	23	USEPA
1997	ND – 0.81	0.26	10	USEPA
1998	ND – 0 14	0.081	17	USEPA

The average total water column PCB concentrations in 1994 were an order of magnitude lower than the early 1980s data. Considering the USEPA's surface water PCB data for 1995 through 1998 (during dredging), the mean PCB concentration was 0.19 ppb (range of 0.042 to 3.5 ppb), an order-of-magnitude or more higher than the pre-remediation concentrations. The annual means are as reported in the table above. Of all the years with water column data, the during-dredging periods show the highest mean PCB detections.

Silt containment has been used during dredging of all three areas. In the North Bay, silt containment included plastic sheeting with wooden shoring at the mouth of the Upper Bay and a silt barrier (filter fabric). In the River Area, silt containment included a silt barrier constructed from surplus wet felt from a nearby paper mill. In the harbor, a silt barrier was used for containment.

In 1998, BBL performed sediment trap sampling in Manistique Harbor. The results showed generally low PCB concentrations in the sediments collected in the traps. However, three of the higher detections observed (9.5, 42, and 84 ppm) suggest resuspension of bottom sediments that may have been due to dredging related activity, including dredged sediment transport by barges to and from the work area. Since no pre-dredging data is available, comparisons with pre-removal conditions are not possible.

2.6 Sheboygan River, Wisconsin

Approximately 3,800 in-situ cy of PCB-containing sediments were removed from the Sheboygan River by Tecumseh Products Company (Tecumseh), the only participating potentially responsible party (PRP), from 17 discrete sediment deposits in the Upper River from 1989 through 1991, using a modified "sealed" clamshell mechanical dredge. Dredging was performed within the confines of a silt containment system comprised of an internal geotextile silt screen and external geomembrane silt curtain. In general, a minimum of two dredge passes (and up to four passes in some areas) were performed in each area followed by sampling and analysis. The first dredge pass was performed in an effort to remove as much sediment as possible (i.e., to hard subgrade material). Following the first pass, the resuspended sediment within the silt containment system was allowed to settle, and a second dredge pass subsequently followed. Additional dredge passes were utilized if post-dredging sampling results exhibited elevated PCB levels (BBLES, 1992; BBL, 1995b, 1998).

The total cost to perform the dredging activities was approximately $445/cy. This unit cost includes materials, assembly, and installation of silt control systems, as well as sediment dredging and barge transport of removed sediment to the PRP's facility, placement of the sediment into the on-site storage facilities, access area development, and monitoring.

Sediment Data:

Pre-removal surficial sediment concentrations ranged from 0.2 to 4,500 ppm (average 640 ppm) in 1987. Post-removal surficial sediment concentrations ranged from 0.45 to 295 ppm (average 39 ppm). Following four dredge passes, one sediment deposit exhibited residual PCB concentrations up to 295 ppm. The USEPA and WDNR agreed that the sediment had been removed to the extent practicable and directed Tecumseh to cap and armor the deposit to contain the sediment and residual PCB (BBL, 1995b). At another Upper River deposit, pre-removal surficial sediment PCB concentrations ranged from 2.6 to 8.2 ppm (average of 5 ppm) with 1.6 to 1,400 ppm (average of 376 ppm) present in subsurface sediment. Following several removal passes, up to 136 ppm remained in a portion of this deposit. Again, the USEPA and WDNR directed that that portion of the deposit be capped/armored. Two other deposits also required capping and armoring to contain elevated residual PCB concentrations following dredging. Removed sediments remain in on-site facilities pending final disposal.

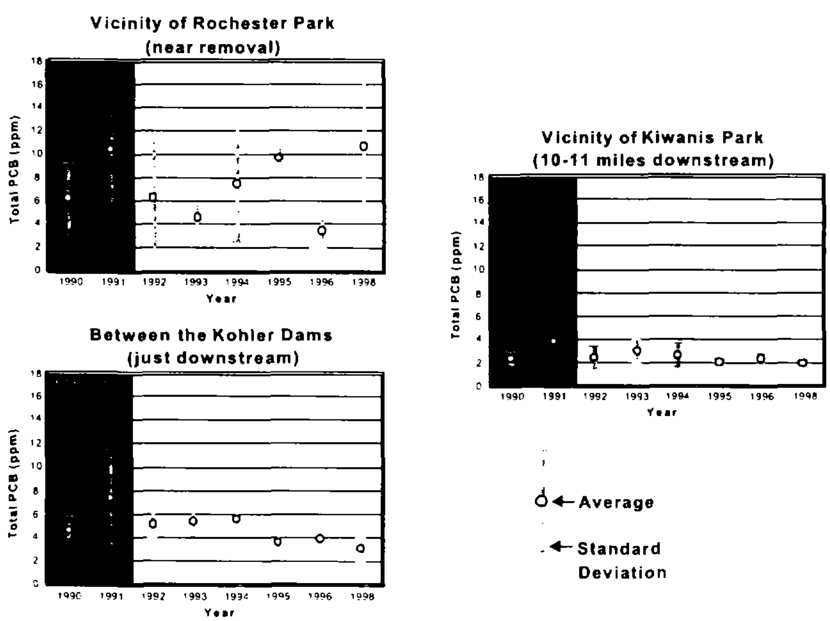
Water Data:

Water-column monitoring activities were conducted before, during, and after sediment removal activities by measuring TSS and/or turbidity and PCB. Monitoring data indicated an increase in PCB concentrations in the water column during dredging. As a result, dredging was halted several times during the project due to increased turbidity, PCB water-column concentrations, or visual observations of sediment migration. Specifically, PCB were detected in one or more fixed downstream sampling stations during 19 of 29 sampling events, with the highest measured concentration of 0.47 ppb detected at a location approximately 500 feet downstream of removal activities. No PCB were detected at the upstream location during that sampling round. Typical causes of elevated PCB or turbidity levels included water disturbances from boats, breaking ice, barges in motion upstream of the sample locations, damaged silt curtains due to high flows, etc. In addition, PCB concentrations within the silt control system were as high as 8.3 ppb (measured 11 days after dredging activities were completed) (BBL, 1995b).

Fish Data:

The figure below shows the smallmouth bass data collected during and after removal activities. Note that no pre-removal data are available due to a laboratory problem. There is no apparent downward trend, and therefore no apparent risk reduction, in the Rochester Park vicinity (area where removal activities were concentrated), despite removal of over 95% of the PCB mass from the targeted deposits and 70% overall mass removal from the Upper River. In addition, although a slight downward trend is evident between the Kohler Dams and in the vicinity of Kiwanis Park, after sediment removal, both locations show an increase in 1991, possibly a result of removal activities.

Sheboygan River - Smallmouth Bass Mean Total PCB Concentrations (1990 - 1996, 1998)



2.7 New Bedford Harbor – New Bedford, Massachusetts

In 1976, the USEPA detected high concentrations of PCB in marine sediments over a widespread area of New Bedford Harbor (i.e., PCB concentrations up to 250,000 ppm were reported in 1982). From May 1988 to February 1989, the USACE performed a full-scale dredging pilot study at the site to assess the performance of dredge equipment, the suitability for the removal of contaminated sediments, and the recommended procedure for operation (USACE, 1990). Three hydraulic dredges were evaluated: hydraulic cutterhead, horizontal auger, and matchbox. The study was performed in two small, shallow (water depth less than 5 feet) dredging areas, and approximately 10,000 cy of sediments were removed (USACE, 1990).

Sediment Data:
Prior to removal, both test areas contained higher concentrations in the surface (top 6-inch) sediments (i.e., average of 226 ppm in Area 1 and 385 ppm in Area 2) compared to subsurface concentrations, which were one to three orders of magnitude lower. Post-removal average residual sediment (top 3-inches) concentrations for each of the dredges tested were as follows:

- cutterhead (Area 1): 80 ppm;
- horizontal auger (Area 1): 66.4 ppm;
- cutterhead (Area 2): 8.6 ppm; and
- matchbox (Area 2): 5.4 ppm.

Note that a theoretical versus actual residual PCB concentration evaluation also was performed, which showed that actual post-removal concentrations were much higher than those theoretically predicted.

Following performance of the Pilot Study, the remediation for the New Bedford site was split into two operable units (OUs). The USEPA issued a ROD for the second OU (hot-spot areas, those areas with greater than 4,000 ppm PCB) in April 1990. The 1990 ROD called for dredging of approximately 10,000 cy of sediment with PCB concentrations greater than 4,000 ppm, dewatering (with effluent treatment), incineration of dewatered sediment, and stabilization of the incineration remains (USEPA, 1990a). The dredging portion of this phase was initiated in April 1994 and was completed in September 1995. Over the 1994-1995 construction period, a total of about 14,000 cy were dredged and placed in a confined disposal facility (CDF) nearby, pending determination of final treatment and/or disposal. Pre-dredging surficial sediment samples (upper 2 feet) had PCB concentrations ranging from 4,000 to 200,000 ppm, with an arithmetic average of 25,000 ppm (USEPA, 1999a). Initial post-dredging sampling showed up to 3,600 ppm PCB remained after dredging (personal communication with P. L'Hreaux of USACE, 1996). After the completion of the project, it was estimated by Ebasco Services and the USEPA that only about 45% of the PCB in the Harbor had been removed by dredging (USEPA, 1997).

The USEPA's ROD for remediation of the second OU, which covers the remainder of the site (approximately 170 acres), was issued in September 1998. The ROD addresses approximately 433,000 cy of sediment within the upper harbor and approximately 17,000 cy of sediment from within the lower harbor and bay. A target cleanup level of less than 10 ppm PCB has been chosen for the upper harbor, with a cleanup goal of less than 50 ppm PCB for the lower harbor and salt marshes. The removed material is to be deposited into four nearshore CDFs. In addition, within areas of public access, and where residences abut the harbor, sediments greater than 25 ppm PCB and greater than 1 ppm PCB are to be removed, respectively (USEPA, 1998b). It is anticipated that dredging would start in 2001 (GE, AEM, and BBL, 2000).

Water Data:

Water-column monitoring was performed during the hot spot removal initiated in 1994 to assess and limit the amount of cumulative transport of PCB to the lower harbor. For the entire removal operation, the USEPA calculated that a mass of approximately 57 kg (24% of the maximum allowable cumulative transport) was transported into the lower harbor (USEPA, 1997b).

Air Data:

During dredging operations, ambient air PCB concentrations were monitored at 16 monitoring locations to characterize impacts from dredging operations. If the airborne PCB concentrations exceeded predetermined action levels (i.e., 0.05, 0.5 or 1 micrograms per cubic meter [$\mu g/m^3$]), then modifications or additions of engineering controls were implemented to dredging operations, with respect to severity. Of 4,041 total samples collected over the course of remedial actions, 1,063 (26 %) exceeded the 0.05 $\mu g/m^3$ action level, 49 (1 %) exceeded the 0.5 $\mu g/m^3$ action level, and 10 (0.25 %) exceeded the 1 $\mu g/m^3$ action level. Due to the exceedences, operational changes were implemented to minimize airborne PCB levels, leading the USEPA to conclude that "control of airborne PCB emissions did contribute to a slower rate of dredging and thus a longer project duration" during the hot spot removal operation (USEPA, 1997b).

2.8 Ruck Pond, Wisconsin

Ruck Pond is one of a series of mill ponds created on Cedar Creek, just upstream of the low-head Ruck Pond Dam. In 1994, an impounded 1,000-foot section of the Creek (Ruck Pond) was drained after a temporary dam was installed on the upstream end and flow was bypassed through siphon piping. The project goal was to remove all soft sediment (contaminated with PCB) down to bedrock, to the extent practicable.

Sediment removal operations were completed in approximately 5 months, and the project cost approximately $7.5 million with a unit cost of approximately $970/cy.

Sediment Data:

A total of 7,730 cy of sediment was removed by dry excavation and disposed of at commercial landfills. After removal efforts were completed, clean materials used for access to the pond were spread along portions of the pond bottom. Although not intended for capping, these materials inevitably provided some containment of the residual sediment, and likely would have reduced (via burial) the relatively high PCB concentrations remaining at the sediment surface that the dredge equipment could not effectively remove (Praeger, Messur, and DiFiore, 1996).

The maximum PCB concentration measured within the sediments was approximately 150,000 ppm, with an average concentration of 474 ppm (USEPA, 1999b). However, 60 soft-sediment surface samples collected from the top 0.5 to 2 feet before remediation exhibited PCB concentrations ranging from non-detectable to 2,500 ppm (arithmetic average 56 ppm). Despite five months of intensive removal efforts (e.g., use of a vacuum truck and squeegees attached to a bulldozer blade), some residual sediment was left on the bedrock surface of the creek bed (Baird and Associates, 1997). Even though 96% of the PCB mass was removed, 7 post-remediation surficial sediment samples exhibited PCB concentrations ranging from 9.2 to 300 ppm (arithmetic average 76 ppm).

Fish Data:

The WDNR measured whole-body PCB congener concentrations in caged fathead minnows at three locations before and after the sediment removal operation (Amrhein, 1997). Three cages were placed at each of three stations: a site in Cedar Creek upstream of Ruck Pond called Cedarburg Pond, a site within the downstream end of Ruck Pond, and a site downstream of the Ruck Pond Dam, located just upstream of Columbia Dam.

In July 1994, just before the start of removal, PCB were measured in caged fathead minnows at the three stations. The average PCB concentrations were 0.12 ppm upstream, 24 ppm at the Ruck Pond station, and 12 ppm at the downstream station (7.1 ppm; 1,700 ppm; and 630 ppm lipid normalized PCB, respectively). The average PCB concentrations measured in caged fish in August and September 1995, about one year after remediation, were 0.09 ppm upstream, 4.2 ppm within the pond, and 11 ppm downstream (2.2 ppm, 170 ppm, and 360 ppm lipid normalized PCB, respectively). These PCB levels in the caged fish collected in Ruck Pond would, at face value appear to have declined 75 to 85%[1] on a wet-weight basis and approximately 90% on a lipid basis after remediation. However, caged fish PCB concentrations at the upstream "background" location also declined 25% wet weight and 70% on a lipid basis one year after remediation, and caged fish concentrations downstream of Ruck Pond declined 10% wet weight and 40% on a lipid basis. The declines upstream of Ruck Pond would indicate that other factors, such as natural recovery processes, or metabolism/feeding differences were occurring.

The other more important issue is that construction activities were taking place in the pond (e.g., siphon installation, work boat traffic, etc.) during the pre-remediation sampling. In fact, all three cages in the pond were displaced from their original locations with one cage unrecovered. Consideration of all of this information indicates that the pre-remediation cages in Ruck Pond should not be considered representative of pre-remedial conditions.

2.9 Waukegan Harbor, Illinois

Waukegan Harbor is approximately 37 acres in size and is located on Lake Michigan approximately 25 miles north of Chicago, Illinois. Remediation areas in the harbor included boat Slip #3 and the 10-acre Upper Harbor. For the Upper Harbor, the USEPA concluded that based on modeling, residual sediment PCB concentrations of between 100 ppm and 10 ppm would result in a negligible PCB influx to Lake Michigan. Based on this, the USEPA set a 50 ppm PCB cleanup level for the Upper Harbor and calculated that 96% of the PCB mass would be removed from the Upper Harbor if the 50 ppm goal was met (USEPA, 1984; 1989a).

The original goal of the ROD was elimination of PCB flux to Lake Michigan (restoration of the harbor fishery was not a specific objective). Regarding the effectiveness of sediment removal, the USEPA stated in the ROD's Responsiveness Summary that, "Remedial alternatives based on a sediment cleanup level below 50 ppm raise technical and cost-effectiveness concerns. The USEPA had to consider the technical limitations inherent in the available dredging technology. Any dredging technique would involve some resuspension of sediment into the water column, and resettling

[1] Two exposure periods occurred in Ruck Pond, 29 and 37 days. Average PCB levels were greater in the longer exposure, indicating that the fish were not at steady state with respect to their exposure sources. Therefore, pre-and post-remediation comparisons were carried out independently for each exposure period. The range of values given reflects the two comparisons.

back into the sediment. It may be difficult to assure that lower sediment levels could be achieved given the technological limitations....As further explained, implementation of the proposed remedy essentially eliminates PCB influx to the Lake from the site."

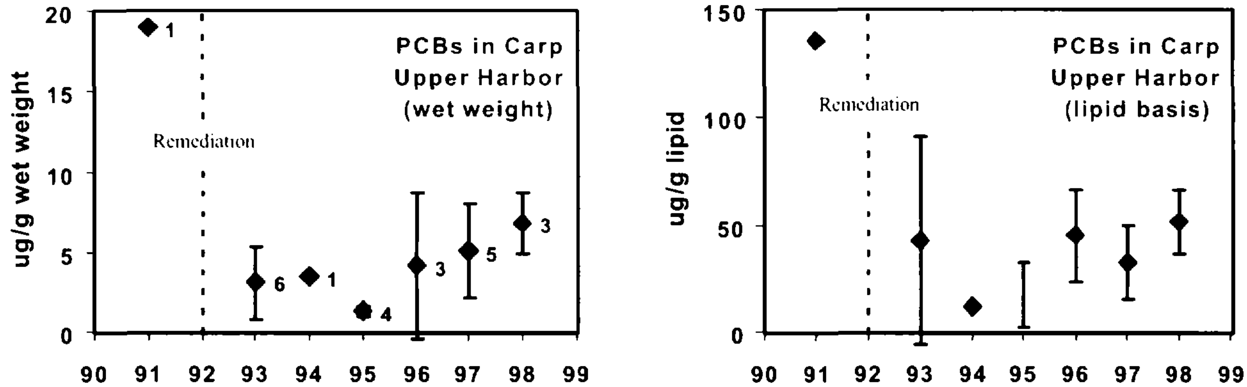
In late 1991 and early 1992, a total of 6,300 cy of sediment with PCB concentrations greater than 500 ppm were hydraulically dredged from Slip #3, and 32,000 cy were hydraulically dredged from the Upper Harbor. Slip #3 was abandoned and prepared as a permanent containment cell. The 6,300 cy were treated by thermal desorption to remove PCB and then placed in the cell. The 32,000 cy from the Upper Harbor were pumped from the dredge directly to the cell, and then the cell was capped. The dredging of sediments (primarily organic silts) in 10 acres of the Upper Harbor was completed to a designated depth and to a designated sediment layer such as clay till or sand. Characterization data had shown the underlying clay till and sand layers were only slightly contaminated with PCB. Sampling was performed during dredging to determine sediment consistency (i.e., to determine if the clay or sand layer had been reached), but not to measure residual PCB concentrations (Canonie Environmental, 1996).

Sediment Data:

No formal post-removal monitoring program was implemented following completion of the dredging, but in April 1996 (over four years after dredging was completed), the Illinois EPA reported the results of "... Harbor sediment samples collected to document the effectiveness of dredging." Thirty surface sediment samples (3-inch depth) were collected from 29 locations. Eleven of the samples were archived in a freezer and not analyzed, and two sample bottles were broken in transit. Results for the other 17 samples (one duplicate) showed PCB concentrations ranging from 3 ppm to 9 ppm. Six of the 17 samples were from within the 10 acres of Harbor that were dredged and had PCB concentrations of 5 ppm to 8 ppm.

Fish Data:

Pre-remediation fish data from Waukegan Harbor are extremely limited. For example, only one carp composite sample consisting of two fish and one alewife composite sample consisting of five fish were collected and analyzed in 1991 by the USEPA. The USEPA also concluded that the 1991 alewife data (as well as additional carp data from 1983) should not be used to assess temporal trends because of technical problems associated with the data. Post-remediation data include several fish species collected in the Upper Harbor and in Lake Michigan in the vicinity of the Waukegan Harbor between 1992 and 1998.



The above figure provides average total PCB concentrations in carp collected from the Upper Harbor (with range representing 2 standard errors). While these graphs seem to indicate that PCB levels were lower in 1993 (compared to 1991), they also indicate a general increasing trend since dredging. The lack of adequate pre-remediation data and the fact that fish tissue concentrations have generally been rising since 1994 indicate the presence of other factors that limit the ability to differentiate the effects of various remedial activities (removal and/or containment) in the harbor. In addition, such a significant drop in PCB from 1991 is inconsistent with expected trends in tissue PCB levels due to rate of natural depuration of PCB by fish.

2.10 River Raisin, Michigan

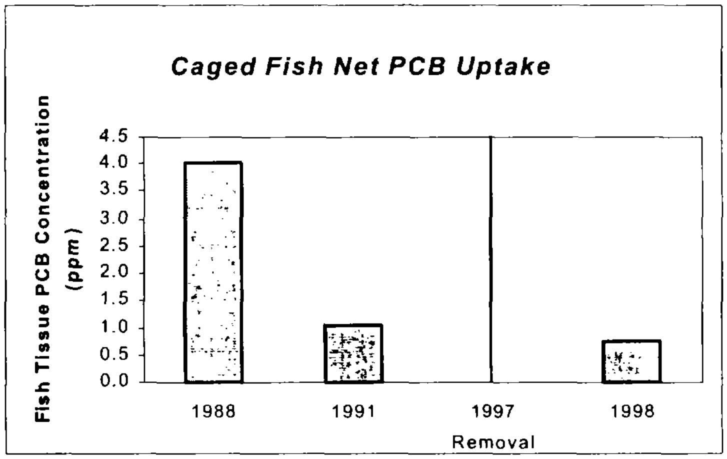
Sediments were removed from an embayment area of the River Raisin adjacent to a former outfall of the Ford Monroe facility. Approximately 27,000 cy of soft sediment were removed from the embayment between April and October 1997 using a mechanical clamshell operation. A silt containment system was also used at the work area perimeter (Metcalf & Eddy [M & E], 1998).

Sediment Data:

Pre-removal surface concentrations ranged from 9.3 to 28,000 ppm (average of 4,130 ppm) and subsurface concentrations ranged from 0.78 to 29,000 ppm (average of 6,510 ppm) (M&E, 1993). The cleanup goal for this site was removal of PCB greater than 10 ppm. Despite removal efforts, potential exposure and risk may not have been reduced because, according to M&E (1998), "confirmatory sample collection activities in many dredge-cells were revealing that sediment remained, even though prior dredging to refusal had occurred." Post-removal PCB levels ranged from 0.54 to 20 ppm (arithmetic average of 9.7 ppm), where only seven of the 14 data points were usable for the post-dredging calculation. The other seven had immunoassay results greater than 50 ppm and were redredged; however no sediment reportedly remained from which to obtain a final confirmatory sample. Two of the suspected sources of sediment were "a 0-0.5 foot layer of sediment deposited following resuspension during dredging" and "sloughing of sediment outside of the SRA (sediment removal area) into the SRA along the base of the silt curtain" (M&E, 1998). Cells not meeting the 10 ppm cleanup goal in surficial sediments were redredged until PCB concentrations were less than 10 ppm in the cells.

Fish Data:

As shown on the figure at right, the Michigan Department of Environmental Quality (MDEQ) performed pre-removal caged fish studies at the mouth of the River Raisin in 1988 and 1991 (remediation occurred in 1997). The total PCB concentration was 4.06 ppm in 1988 and 1.07 ppm in 1991 (MDEQ, 1998). In comparison, the PCB concentration after removal in 1998 was approximately 0.77 ppm. The 1991 concentration was about 25% of the 1988 concentration (a decrease of about 1 ppm/year), and the 1998 concentration was about 72% of the 1991 concentration (a decrease of about 0.04 ppm/year), thus indicating that natural recovery was taking place prior to removal activities and that removal activities did not have a marked effect in reducing the post-removal caged fish concentrations.

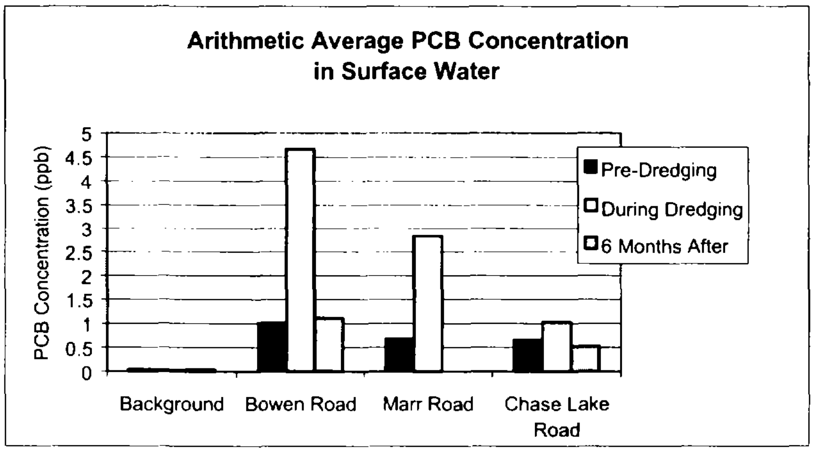


2.11 Shiawassee River, Michigan

In 1982, a backhoe was used to remove PCB-containing sediment from around a factory discharge, and a dragline was used to remove PCB–containing sediments near Bowen Road, 1.2 miles downstream from the plant site. Small pockets of oily sediments also were vacuumed from this stretch. As discussed by Malcolm Pirnie, "although intended to clean up a total of eight miles of the river, the remediation project stopped at the end of 1982 with only 1.5 miles of river remediated. Cost overruns and the presence of contamination extending farther than initially anticipated were identified as reasons for the incomplete removal action" (Malcolm Pirnie, 1995). No post-removal verification sampling was performed to determine if the 10 ppm cleanup goal was achieved. Only visual and olfactory observations were used to determine the extent of dredging [Environmental Research Group (ERG), 1982].

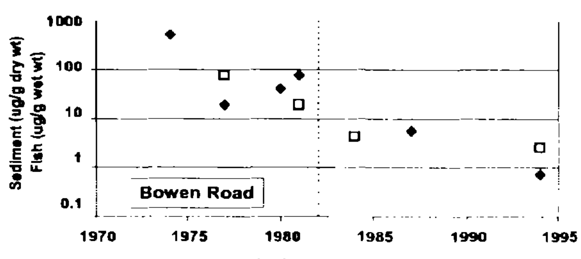
Water Data:

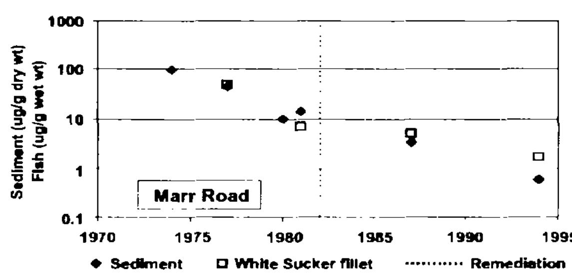
Rice et al. (1984) investigated changes in PCB concentrations in surface water before, during, and after dredging. The results are summarized in the figure below. The two downstream locations show increases in PCB concentrations during dredging; however, the samples collected six months later do not show a significant decrease in PCB concentration when compared to the pre-dredge concentrations. In fact, it was recognized that "dredging of sediments is likely to cause temporary resuspension of contaminants into the water column which can cause a temporary increase in tissue contaminant concentrations of aquatic biota. Dredging also removed indigenous benthic fauna, which can take years to reestablish" (Malcolm Pirnie, 1995).



Sediment and Fish Data:

The set of graphs presented below show total PCB concentrations in sediment and white sucker fillet samples from the Shiawassee River. Twenty years of data indicate that PCB levels in fish and sediment were undergoing a decline prior to and after the 1982 remediation, which limits the ability to differentiate the effects of remediation versus other processes such as natural attenuation or source control. Note that data are plotted on a log scale.





To assess the effectiveness of the cleanup, the University of Michigan (UM) performed caged fish and clam studies in the Shiawassee River on behalf of MDEQ (formerly Michigan Department of Natural Resources) before, during, and after the 1982 dredging effort (Rice and White, 1987). At all locations downstream from the plant site and in the area of removal, the UM study indicated an increase in the bioavailability of PCB following dredging (Rice et al., 1984). For example, at the Bowen Road location (1.2 miles downstream of the source), the PCB levels in caged fathead minnows increased from 64.5 ppm (before removal) to 87.95 ppm dry weight after dredging. PCB concentrations in caged clams collected approximately ¼-mile downstream from the plant site ranged from 13.82 ppm before dredging to 18.30 ppm after dredging, and averaged 59.1 ppm during dredging (Malcolm Pirnie, 1995; Rice et al., 1984), indicating that dredging actually increased exposure rather than decrease it as intended.

2.12 Willamette River, Oregon

A dredging remediation project was undertaken in the Willamette River in Portland, Oregon under the auspices of the Oregon Department of Environmental Quality (ODEQ). The remedial objective was to remove approximately 100 cy of sediment to the extent practicable, up to a depth of 2 feet. Diver-assisted low-volume dredging was performed utilizing a vacuum pump/suction hose operation to remove a small sediment volume. Approximately 45,000 pounds of sediment containing PCB were removed while working around large debris.

According to the final report on sediment remediation, "dredging to a 2-foot depth was not achievable in the majority of the areas because of the presence of debris and large rocks." In fact, only approximately 14 cy of sediment actually were removed. PCB concentrations were detected as high as 190 ppm (average 29 ppm) prior to dredging, with an average PCB concentration of 8 ppm (and a high of 21 ppm) after dredging. A sediment cap was placed over the entire area from which sediments were removed (CH2M, 1991).

2.13 Duwamish Waterway, Washington

Sediment Data:

A dredging effort was implemented at Slip 1 of the Duwamish Waterway to cleanup sediment from a 255-gallon PCB spill which occurred on September 12, 1974. Pre-removal PCB concentrations at the spill site were detected in excess of 30,000 ppm (Blazevich, 1977). The first phase of remediation was conducted in October 1974 using divers with hand-held dredges to remove approximately 50 cy of sediment (Willmann, 1976). Post-phase I removal concentrations ranged from 1,200 to 1,900 ppm (Blazevich, 1977). Prior to implementation of Phase II dredging activities in 1976, surficial (top 1 foot) PCB concentrations ranged from non-detect to 42 ppm (average of 4 ppm). Extensive dredging was performed with a PNEUMA pump dredge in an effort to achieve maximum PCB removal near the spill source.

After the first dredging pass, sediment PCB concentrations increased to as much as 2,400 ppm. Thus, several passes were employed to achieve maximum removal. According to Willmann (1976), it was originally thought that 4 feet of dredging would be required to sufficiently reduce the concentrations. However, it was found that surface sediment still contained about 200 ppm after 6 feet of material had been removed, so additional dredging to hardpan (a depth of about 10-12 feet) was performed and resulted in residual PCB concentrations of about 10 ppm (Willmann, 1976). Overall, the post-dredge surficial sediment PCB concentrations ranged from 0.2 to 140 ppm (average of 7 ppm), which were higher than the Phase II pre-removal concentrations of non-detect to 42 ppm (average of 4 ppm).

2.14 Marathon Battery, New York

A total of approximately 100,000 cy of sediments were removed from two marsh/cove areas (East Foundry Cove Marsh [EFCM] and Foundry Cove) in the lower Hudson River, New York area. The September 1986 ROD for Area I (EFCM and Constitution Marsh) selected hydraulic dredging of 23,000 cy of sediments from the EFCM with cadmium concentrations greater than 100 ppm (USEPA, 1986). The September 1989 ROD for Area III (East Foundry Cove, West Foundry Cove, and the Hudson River adjacent to the facility) selected hydraulic dredging of 55,000 cy of sediments from the East Foundry Cove to a depth of one foot. By removing the top foot, the USEPA believed that 95% of the cadmium would be removed. It was anticipated that the post-dredging concentrations would be less than 10 ppm (USEPA, 1989).

Dredging operations in the marsh areas utilized a custom-made horizontal auger mounted on an all-terrain vehicle; while dredging in the cove/open water areas utilized a barge-mounted clamshell mechanical dredge. The barge was able to be used in low water depth areas.

Dredged sediments were pumped to a settling basin. Dewatered solids were transported off site for landfill disposal. Wastewater was treated and discharged into the cove.

Post-dredging monitoring of sediments was conducted. In one marsh area, sediments were excavated, not dredged. The average post-excavation concentration was approximately 25 ppm for cadmium with no sample exceeding 100 ppm (cleanup goal). This area was subsequently capped with BentoMat. In one cove area, the average post-dredging cadmium concentration was less than 10 ppm with a maximum detection of approximately 20 ppm. However, large boulders prevented dredging of a portion of the area.

2.15 United Heckathorn, California

Approximately 108,000 cy of sediments were removed in 1996 from the Lauritzen and Parr channels in Richmond Harbor, California. The goal of the removal action was to meet a DDT target level of 590 ppb, as well as human health risk criteria and surface water criteria. The ROD estimated that 65,000 cy of sediments would be removed (USEPA, 1994).

Sediments were dredged mechanically using barge-mounted 7 cy and 12 cy Cable Arm clamshell bucket dredges. Sediment removal averaged approximately 640 cy per day. After sediment removal was completed, a 6-inch clean sand layer was placed (by hydraulically pumping) throughout the dredged areas. Dredged sediments were dewatered and subsequently stabilized (0.037 tons cement and 0.026 tons sodium silicate per cy of sediment). Stabilized sediments were transported by railcar to two commercial landfills.

Dredging verification was performed using a depth target. A 50-foot grid system was established to track the dredging. Numerous core samples were taken to verify removal of "young bay mud" and penetration into "old bay mud" (the depth target). If at least three of five cores showed "old bay mud," the dredge moved on. In selected grids, after reaching the depth target had been verified, the USEPA took samples from the top 6 inches of the verification cores and analyzed for DDT and dieldrin. Seventeen such samples were collected from the Lauritzen Channel cores which showed 1) average DDT concentration of 263 ppb, 2) median DDT of 44 ppb, and 3) maximum DDT of 1,300 ppb. Maximum dieldrin detected was 55 ppb. Three such samples were collected from the Parr Canal cores which showed 1) average DDT of 200 ppb, 2) median DDT of 200 ppb, 3) maximum DDT of 1,500 ppb, and 4) non-detectable dieldrin.

A post-dredging mussel program was initiated, similar to California's "mussel watch" program. Mussels were transplanted from the outer coast to four locations within Richmond Harbor -- one in the middle of the harbor, one at the edge of the remediated area, one upstream and one downstream of the remediated area. Five years of mussel monitoring are planned. Year one lipid-corrected DDT concentrations in mussels were reportedly lower than pre-dredging concentrations.

Difficulties encountered as part of the channel dredging project included silt curtain damage, disposal site load refusals, and public controversy regarding disposal. Due to silt curtain management issues, an additional 14 days of delays were experienced during the project. These issues included propeller damage from tug boats moving vessels in the adjacent Santa Fe Channel, and also during two days of extreme tides. Removal operations adjacent to the curtain were performed last and on an outgoing tide to prevent tearing the curtain with the dredge bucket. The cumulative delays from the silt curtain maintenance in the Lauritzen Channel were 23 days over the entire project (Chemical Waste Management, 1997).

Additionally, the disposal site originally intended for use (the WMI Midway Landfill near Pueblo, Colorado) was not used. The Midway site declined to accept project material after 43 railcars of sediments from the Parr Canal had already been loaded. The first trainload was dispatched to the alternative site, the WMI Butterfield Station Facility at Mobile, Arizona, a RCRA Subtitle D facility. In spite of the site's suitability and prior approval by the USEPA, Greenpeace and local residents protested the shipments of United Heckathorn sediments, which attracted substantial media attention. The USEPA conducted public outreach activities, and shipments to Butterfield continued. Ultimately, the East Carbon Development Corp. facility in Utah was used as the sediment disposal site.

2.16 Bayou Bonfouca, Louisiana

Approximately 169,000 cy of sediments were removed in 1995 from Bayou Bonfouca, Louisiana. Cleanup goals specified removal of sediments containing polynuclear aromatic hydrocarbons (PAHs) greater than 1,300 ppm, with on-site incineration. A custom-made 5.2 cy barge-mounted bucket excavator was used to achieve a 3-inch dredging tolerance (GE, AEM, BBL, 2000).

Control measures during dredging included five layers of silt curtains, a log boom and sheetpiling along the bayou banks. Sediments were pumped to an on-shore retention/dewatering/treatment/incineration facility.

No post-dredging sampling was performed immediately after dredging. Later post-dredging sampling was performed in 1997 for sediments, water column, and five species of fish: largemouth bass (15 samples), redear sunfish (7 samples), freshwater drum (5 samples), white bass (1 sample), channel catfish (5 samples). Sediment samples were analyzed for PCB (3 samples) and semi-volatile organic compounds (SVOCs) (10 samples); water column samples were analyzed for SVOCs (10 samples); and fish samples analyzed for arsenic, total lead, PCB and SVOCs.

Analytical testing reported the following maximum concentrations:

- Sediment PCB - 0.39 ppm (Aroclor 1248)
- Sediment SVOCs - 47.7 ppm dry weight; 16.1 ppm wet weight (both di-n-butylphthalate)
- Water SVOCs - 47.7 ppm dry weight; 16.1 ppm wet weight (both di-n-butylphthalate)
- Fish arsenic - 0.1 ppm (largemouth bass)

- Fish total lead - 0.06 ppm (largemouth bass)
- Fish PCB - 86.4 ppb (white bass/Aroclor 1232)
- Fish SVOCs - 203.6 ppm dry weight, 37.6 ppm wet weight [both bis (2-ethylhexyl) phthalate] (GE, AEM, BBL, 2000)

2.17 Black River, Ohio

Approximately 60,000 cy of sediments were removed in 1989 and 1990 from two "hot spots," comprising an 8-acre area, in the Black River, Ohio. Sediments were removed using a hydraulic cutter dredge, as well as a mechanical clamshell dredge in debris-laden areas. Dredged materials were discharged into rolloff boxes for on-site disposal (GE, AEM, BBL, 2000).

Water samples were obtained from the Black River to monitor water quality during the dredging operations. A sample was obtained from the upstream sampling point and the downstream sampling point prior to dredging and for two weeks after dredging. In addition to the upstream and downstream samples, variable point samples were taken immediately downstream (200 yards) of each dredge during sediment removal operations. Sample analyses consisted of total suspended solids, total cyanide, oil and grease, total cadmium, turbidity, and PAHs. Additionally, post-dredging soundings were compared to pre-dredging soundings to verify dredging to natural till (USX, 1991).
Extensive long-term fish sampling of the entire river was performed by the National Biological Survey and Ohio Environmental Protection Agency both during pre- and post-dredging periods. Annual sampling activities were conducted from 1992 to 1995. High tumor frequencies in fish and increased PAHs in surface sediments were observed in the early 1990s, after dredging operations. Fish tumor frequency dropped based on 1994 data (Baumann, 1995).

Total costs for the project amounted to $5 million, or approximately $83 per cy.

2.18 LTV Steel, Indiana

Approximately 109,000 cy of PAH and oil-contaminated sediments were removed from 1994 to 1996 from a 3,500 foot long intake channel between the LTV Steel plant and the Indiana Harbor Canal in East Chicago, Indiana (GE, AEM, BBL, 2000).

The bulk of the sediments were removed using a hydraulic dredge (10- and 12-inch cutter heads), with the remainder removed using diver-assisted vacuum dredges. The remedial goal specified removal of sediment to the underlying slag fill or natural hard pan (Floyd Browne Associates, Inc., 1993). Dredged solids were dewatered and transported to a state special waste landfill.

Due to concerns about water quality during hydraulic dredging, turbidity was continuously monitored at the intake, and a limit of 10 NTU above background was set (requiring shutdown of dredging if exceeded). Water quality was also monitored daily 200 feet downstream of the dredge. During the 1995 and 1996 seasons, the average turbidity recorded directly downstream of the dredge was 4.2 NTU and ranged from 2 to 10 NTU. The average background turbidity was 3.8 NTU. No significant change in turbidity was recorded at the fixed 24-hour continuous monitoring station during the removal operations. Additionally, sonar profiling surveys (pre- and post-dredging) were used to monitor dredging completion.

Total project costs amounted to $12 million, or approximately $110 per cy of sediment removed (GE, AEM, BBL, 2000).

2.19 Commencement Bay, Washington

The Commencement Bay Superfund site project included dredging of the Sitcum and Blair waterways. The combined navigational and cleanup dredging project was implemented from October 1993 through September 1994. Contaminants of concern were metals and PAHs. The cleanup target was dredging of the contaminated sediment plus 2 additional feet in the Sitcum Waterway and dredging to achieve navigational depths in the Blair Waterway. For both waterways, a total of 2.83 million cy were dredged and moved to the abandoned Milwaukee Waterway. Hydraulic dredges (10, 12, and 26-inch cutterheads), as well as mechanical clamshell dredges (8 and 15 cy buckets) were used for sediment removal. The total included 2.4 million cy of clean sediments from the Blair Waterway and 425,000 cy of potentially-contaminated sediments from the Sitcum Waterway. Only about 30% of the sediments from the Sitcum Waterway proved to be contaminated (GE, AEM, BBL, 2000).

To create a disposal facility, the Milwaukee Waterway was bermed at its mouth, with a weir and overflow pipe (to the Bay) installed. After placement of the dredged material, and a multi-year period of settling, the filled waterway was paved over.

Compliance requirements were set at the point of dredging and at the point of disposal. Since most of the material from the Blair Waterway was clean, the monitoring requirements at the point of disposal included only such parameters as dissolved oxygen, turbidity, and temperature. For the Blair and Sitcum Waterway contaminated material, the monitoring frequency was set at three times per day at the point of dredging and three times per day at the point of disposal. The three times per day requirement was relaxed after a period of time since monitoring indicated that compliance was being met. The compliance limits were set based on both elutriate sampling and theoretical modeling. Metals, TSS, and cyanide were used as compliance parameters. No major violations of the compliance parameters have been reported (Cushing, 1994).

Total project costs amounted to $17.5 million, or approximately $6 per cy (GE, AEM, BBL, 2000).

2.20 Lake Järnsjön - Sweden

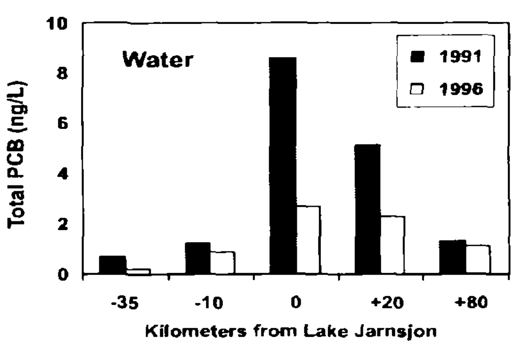
Lake Järnsjön is a 62-acre lake located 72 miles upstream of the mouth of the Emån River in Sweden. In 1993/1994, approximately 196,000 cy of PCB-containing sediments were removed from the lake.

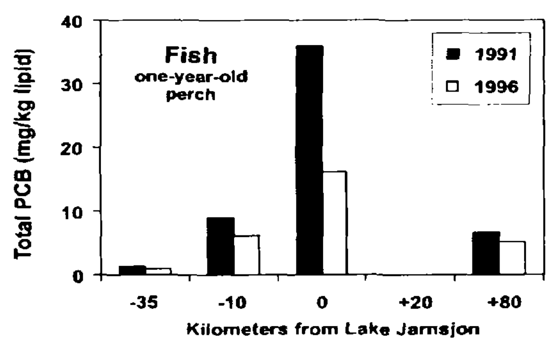
Sediment Data:

Pre-removal PCB concentrations in sediment in 1990 and 1992 ranged from 0.4 to 30.7 ppm (average 8.1 ppm) in the top 1.3 feet and 0.18 to 2.9 ppm (average 1.5 ppm) in the top 0.1 foot (Bremle, Okla, and Larsson, 1998). Sediment remained following dredging with post-removal concentrations ranging from 0.01 to 0.85 ppm (average 0.13 ppm) from the top 0.66 feet (Bremle, Okla, and Larsson, 1998).

Water and Fish Data:

Although this project appears to have been successful in reducing surficial sediment PCB concentrations, review of the fish data indicate that PCB in the lake continue to influence fish concentrations.





The two graphs shown above depict total lipid-normalized PCB concentrations in fish (one-year-old perch) and water from the Emån River, comparing 1991 pre-remediation levels with 1996 post-remediation levels. Spatial trends are also apparent and indicate that while PCB concentrations decreased by approximately 50% in Lake

Järnsjön, upstream and downstream concentrations were also on the decline likely due to ongoing system-wide natural recovery processes. Finally, it is apparent that even after dredging an estimated 97% of PCB mass from the entire bottom of Lake Järnsjön, lake sediments remain a dominant source of PCB to fish and the water column (FRG, 1999).

3.0 Summary

A review of these sites shows that efforts at dredging sediments containing PCB have exhibited varied removal efficiencies, even with repeated passes. Greater efficiencies have been achieved only in some small-scale, specialized removals, and even then remedial goals, if expressed as PCB cleanup levels, have not been met. Efforts to achieve maximum PCB removal at Duwamish Waterway using the PNEUMA pump dredge left 50 ppm PCB in the sediments (USEPA, 1977). During the pilot study, USACE achieved reductions in PCB from the 150 to 280 ppm range to the 5 to 80 ppm range in New Bedford Harbor (where the USEPA has subsequently proposed a 50 ppm cleanup goal, with limited removal to 10 ppm in sensitive biological areas) with a hydraulic cutterhead dredge. Up to 2,068 ppm remain in the dredged "hot-spot" areas of New Bedford Harbor. Use of a horizontal auger hydraulic dredge at the Grasse River in New York reduced PCB levels from the non-detect to 11,000 ppm range (average of 1,109 ppm) to a 1.1 to 260 ppm range (average of 75 ppm). Results from mechanical dredging at the Sheboygan River and Harbor Site exhibited highly variable residual PCB concentrations up to 295 ppm. Small-scale vacuum pump/suction hose operations at the Willamette River site were not capable of removing 2 feet of sediment and resulted in residual PCB concentrations up to 21 ppm. Even the excavation "in-the-dry" remediation techniques used at Ruck Pond were not capable of removing all sediment containing PCB. After much effort to remove sediment to the extent practicable, residual PCB concentrations still ranged from 10 to 300 ppm.

In general, the available monitoring results of environmental dredging at the sites described above have indicated that low PCB cleanup levels (e.g., in the range of 1 to 10 ppm) are not achievable on a consistent basis. Furthermore, it has been stated that "no existing dredge type is capable of dredging a thin surficial layer of contaminated material without leaving behind a portion of that layer and/or mixing a portion of the surficial layer with underlying clean sediment" (Palermo, 1991). Therefore, even though the dredge may be capable of removing substantial volumes of sediment, the sediments which the dredge cannot remove (or those that eventually settle as a result of resuspension) could remain as a potential future PCB source.

Additional general observations from these projects are as follows:

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- The magnitude of sediment removal is much lower than a typical maintenance dredging project;
- All targeted sediments could not be removed;
- Residual sediments containing chemical constituents remained following removal, in some cases at higher levels than before removal;
- Sediments (including associated chemicals) resuspended during removal can migrate outside of the removal area, even with the use of silt control systems; and
- Dewatering requirements (for subsequent sediment disposal) can significantly retard removal productivity.

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Appendix E

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engineers & scientists

Development of a Sediment Removal Alternative for the Kalamazoo River

Appendix E - Development of a Sediment Removal Alternative for the Kalamazoo River

1.0 Introduction

This appendix describes the fundamental engineering principles and assumptions used in the development of the sediment removal alternative that is evaluated in the Kalamazoo River Feasibility Study (FS). The remedial alternative includes removal of submerged sediment in the river through hydraulic dredging, transport of the dredged sediment through a hydraulic pipeline, and disposal of the sediment in a series of upland confined disposal facilities (CDFs) (Alternative No. 5 in the FS). The removal alternative described in Section 5 of the FS was developed using remedial technologies and process options retained after the screening of remedial technologies and process options described in Section 3 of the FS. This remedial alternative also includes stabilization of the exposed sediment on the banks of the three former impoundment areas, institutional controls, and monitoring.

This appendix also describes the site-specific physical characteristics and assumptions that were considered during the development of the removal alternative. The physical characteristics considered in developing this alternative are based on field and analytical information obtained during the Remedial Investigation (RI) work efforts and include:

- Polychlorinated biphenyl (PCB) distribution in sediment and surface water;
- Hydrologic condition and overall surface water quality; and
- Physical characteristics of the river.

In addition many of the assumptions used to develop this alternative are based on actual field experience that has been gained on other environmental dredging projects. These experience(s) provide information on the following three factors:

- Effectiveness of removal as measured by the reduction in surface sediment PCB concentrations;
- PCB losses during removal; and,
- Removal productivity (i.e., sediment removal rate in terms of cubic yards per hour [cy/hr]).

All this information is important because they are the essential facts used to evaluate the performance of the remedial alternative. This appendix also concludes with a general description of the sediment removal alternative and provides cost estimates used within the detailed evaluation of remedial alternatives presented in Section 4 of the FS.

In this appendix, the information used to develop the removal alternative are presented in the following sequence:

- Site-specific characteristics;
- Sediment removal approach;
- Sediment removal process options and their effectiveness; and
- Transportation and disposal options.

Lastly, the appendix summarizes the remedial alternative that is presented and evaluated in Section 5 of the FS.

2.0 Factors Considered in Developing The Removal Alternative

This section provides detailed information on the factors considered in the development and evaluation of the sediment removal alternative for the Kalamazoo River. This information includes data on PCB distribution, physical characteristics of the river and surrounding areas, and factors influencing the removal, transportation, and disposal of the PCB-containing sediment. This section also includes a summary of specific technology types and process options used to develop the removal alternative. Specifically this section describes the following:

River specific characteristics:

- Distribution of PCB in sediments;
- Removal volumes;
- Water depth and river width;
- Obstacles to removal activities;
- River bank stability; and
- Access issues.

Evaluation of sediment removal technologies:

- Comparison of wet removal techniques; and
- Dry removal techniques.

Description of process options:

- Assessment of process option effectiveness;
- Process option productivity and implementation; and

- Potential environmental impacts.

2.1 Site-Specific Characteristics

The development of a remedial alternative must take into account site-specific characteristics as they influence the effectiveness, implementability, and cost of a given alternative. These characteristics may also affect other evaluation criteria used in the FS process including short-term impacts on the environment and the surrounding community. For the Kalamazoo River system, the critical characteristics include the distribution of PCB within the river sediment and the physical features of the river and shoreline areas. The physical characteristics of the system considered in the development of the removal alternative included water depth, the presence of debris in the system (i.e., along the shoreline of the river and on the bottom of the impoundments), general access to the river, and overall stability of the river bank. Each of these characteristics for the river is discussed further below.

2.1.1 Distribution of PCB in Sediment and Removal Depths/Volumes

As described the RI, PCB-containing sediment is distributed throughout the entire 52-mile reach of the river. In general, the volumes of PCB-containing sediment are greater in the lower energy depositional areas of the river including the current and former impoundment areas. However, there are no localized areas with elevated sediment PCB concentrations, or hot spots where a large mass of PCB is contained within a small volume of sediment such that removal would have a significant impact on risks at the site. The distribution of low concentrations of PCB in sediment throughout the site has a direct impact on remedy development. The rationale for bank-to-bank conceptualization of dredging is presented in Section 2.5 of the FS. This river-wide bank-to-bank removal volume estimate was developed by:

1. Identifying the maximum depth of PCB detected in the sediment for each river segment along the 52-mile reach of the river;
2. Adding an additional 6 inches of depth to this initial depth to compensate for the inaccuracy of available removal technologies;
3. Using the 90^{th} percentile of this data to estimate the initial volume of PCB-containing sediment; and,
4. Adding an additional 6 inches to the depth for a "second-pass" removal step.

The resulting removal depths along the river are presented on Figure 1 and demonstrate that removal would be required at depths ranging from a minimum of 24 inches in the vicinity of river mile 10, up to a maximum of 5½ feet just upstream of the Otsego Dam. It is important to note that the removal depths were estimated assuming a two-phased removal process, with a combined overdepth removal of 12 inches (6 inches on each step), and do not include provisions for additional removal that may be required to achieve a target PCB concentration in the sediment. Using the optimistic assumption that a two-step removal process will achieve the project objectives, approximately 16 million cy of submerged sediment would be removed based on the depths identified on Figure 1. The estimated sediment volume on a per reach basis, including the first and second passes, is presented in Table 1. It is important to note that a majority of sediment volume is associated with the impoundment areas with over 65% of the sediment associated with Lake Allegan.

2.1.2 Water Depth and Width of the Kalamazoo River

Two key factors that can dramatically influence the method of sediment removal from a river system include the available water depth and width of the river. For the Kalamazoo River, the width of the main portions of the river ranges from 50 to 400 feet, but is typically 100 to 200 feet. The river widens in the impounded areas where the width ranges between 400 to 2000 feet. The width of the secondary channels in the braided reaches and around island formations may range between 20 to 100 feet. The river is generally very shallow with water depths ranging from 1 to 8 feet in the main portions of the river. Some of the areas in the impoundments are not navigable even with a small boat.

To assess the feasibility and techniques for dredging in the Kalamazoo River, water depth and river width information between Morrow Dam and Lake Allegan Dam were compiled. These data were collected between August 1993 and February 1994 (BBL, 1994) and are presented in Table 2. Segmentation of the river in Table 2 corresponds to the reaches identified on Figures 2 through 9. The table also shows the proposed removal depths for various river reaches for the Kalamazoo River taken from Figure 1. Based on the water depth data, any water-borne construction equipment considered for use on the river must draft less than 2.5 feet. While some areas of the river often have less than 2.5 feet of water, it would be possible to start removal operations in the deeper water areas, and dredge a channel to access the shallow areas. Such shallow water conditions would create implementation challenges for both hydraulic and mechanical dredge equipment. Once dredged, the ability to pump directly to a CDF using hydraulic dredging techniques may pose some benefits, compared to mechanical techniques which require scows and work boats to transport the sediment. In a limited number of shallow water stretches where access from shore is feasible and/or the river can be temporarily diverted and dewatered to allow removal in the dry, use of mechanical removal techniques may be most appropriate.

In summary, the shallow water depth areas of the river do not preclude sediment removal from the water, but may significantly constrain productivity given the need to create either "dry" conditions or sufficient draft for the equipment to operate in. These water depth-related constraints on productivity may be reduced through the use of a hydraulic dredge rather than a mechanical dredge, given the near-field support equipment requirements of mechanical dredging operations. Alternative approaches to water-based dredging may have some applicability in certain non-impoundment reaches of the river including mechanical removal in the wet using shoreline-based equipment and/or the potential use of sheetpiling, portable dam structures, or earthen berms to facilitate excavation in the dry. However, the applicability of these techniques may be limited to narrow non-impoundment reaches of the river provides sufficient shoreline access is available.

There are several narrow areas of the river that present implementability issues relative to locating and effectively operating sediment removal equipment within or adjacent to the river. Similar to available water depth, the potential challenges associated with the width of the river may be greater if water-based mechanical removal equipment were used. Again, this is a function of the size and amount of equipment used to support a mechanical removal operation from the water.

There are several specific areas of the river where it may be difficult to conduct water-based sediment removal based on the available water depth and river width. The areas are typically shallow marsh-type areas, braided river segments with narrow channels, or shallow sediment deposits in the impounded lakes and include the following:

- <u>Otsego City Impoundment</u>: This reach, particularly the segment immediately downstream of Plainwell Dam, is characterized by a braided channel system. The river flows in narrow channels around a large number of channel bar formations. Some of these channels range between 20 to 40 feet in width with average water depths between 1 and 2 feet.

- <u>Allegan City Impoundment</u>: Large sediment deposits and shallow water depths (about 1 foot) are present in this reach between Transects KPT 132 and 135.

- <u>Lake Allegan</u>: Two shallow areas were identified in this reach, one between Transect KPT 142 and 143, and the other at KPT 148. The area between KPT 142 and 143 has a number of islands formed in the river, and sediment deposition in this area may result in shallow water depths. The area at Transect KPT 148 is also another low energy area with a large sediment deposit forming in mid-channel. This area is approximately 500-foot wide with water depths of about 1 foot.

As discussed above, the width and depth of the river do not preclude water-based sediment removal operations. Rather, they serve to limit the productivity that can realistically be achieved in removing the sediment and limit the applicability of water-based mechanical dredging as an applicable removal technology. However, some areas of the river may be amenable to sediment removal from the shoreline or through excavation in the dry.

2.1.3 Debris and Other Obstructions

The bank areas for much of the river are characterized by low to dense tree and shrub growths down to the water line. Fallen trees, snags, and overhanging branches are present in most areas. As such, extensive clearing along the shoreline and in the water will be required to allow access for sediment removal equipment. Available data indicate that significant areas of the bottom of Lake Allegan may be covered with tree stumps and whole trees associated with land that was forested prior to the creation of the impoundment. This debris would require a significant level of effort to remove prior sediment dredging. To confirm this assumption, a survey of the bottom of Lake Allegan was conducted by a dive team in August 2000 and is discussed in the Supplement to the Kalamazoo River RI/FS (BBL, 2000d).

The debris will serve to limit the productivity of any sediment removal operations. While mechanical equipment such as a small crane mounted on a shallow-draft barge can be used to effectively remove debris, watertight clamshell dredge buckets that are often used for environmental dredging projects are sensitive to debris and may not close properly unless the debris has been thoroughly removed prior to dredging operations. If a watertight clamshell does not close properly due to debris, sediment will leak out of the bucket as it is pulled up through the water column greatly increasing the amount of sediment resuspension and PCB migration associated with removal operations. Similarly, if hydraulic dredging techniques are utilized, the presence of debris could significantly slow down production rates and limit dredging effectiveness. At PCB removal sites like the St. Lawrence River, New York, and Waukegan Harbor, Illinois, diver-assisted and mechanical removal techniques were employed to remove debris prior to initiating hydraulic dredging.

The riverbanks near cities and towns contain industrial and/or residential developments. Industrial/residential developments were mainly noted in the reaches between River Miles 0-6 in Kalamazoo (0-mile starting at Morrow Dam), River Miles 19-29 in Plainwell and Otsego, and River Miles 40-47 in the City of Allegan. The area surrounding Lake Allegan between River Miles 47-52 has sparse residential developments with the remaining areas generally wooded and undeveloped. Riverfront developments that typically result in bulkheads, sheetpiles, and riprap banks account for less than 2 percent of the total length of the river banks. Other shoreline structures include boat launches and docks (few and sparsely located), nearshore roadways, parking lots, yard areas, landfills, etc., which present engineering challenges in terms of the stability of these structures during or following a removal operation. The reaches between River Miles 6-19 and River Miles 28-40 represent free river reaches and the river banks are generally occupied by gravel pits, farm lands, or undeveloped wooded areas.

Other obstructions in the area that would limit access to the river sediments include approximately 27 highway and 5 railway bridges located between Kalamazoo and Lake Allegan. The clearance (the distance between the bridge structure and water level) is generally small, ranging approximately between 8 and 12 feet. Other potential obstructions include dam structures for the current impoundment areas as well as the sills of the dam structures for the former impoundment areas. The combination of bridges and dams limits the physical continuity of the river system and would require multiple access and staging locations along the river to facilitate construction. In some cases, near the structures, the use of specialized construction equipment (shallow-draft) and/or land-based construction approaches may be required to facilitate removal.

2.1.4 Bank Stability

The Kalamazoo River traverses a large outwash plain with natural soils that are predominantly sands, gravels, and cobbles. This is evident in areas with exposed banks and from the numerous local gravel pits where these deposits are mined. The floodplain areas also contain marsh-type vegetation including grass, shrubs, and trees. Some of these marshes contain tree growths that are 30 to 50 feet tall indicating strong substrate foundation (i.e., older deposits). Tree growths in the banks generally represent older growths with the trees ranging from 30 to 50 feet in height. Tree counts were performed along the banks of the Kalamazoo River to estimate tree density. This information is presented in the Supplement to the Kalamazoo River RI/FS.

Parts of the river bank are currently unstable and contain active erosional areas as well as steep (1 horizontal: 1 vertical [1H:1V] or steeper) and high river banks. Bank heights vary from several feet to about 60 feet in some places. The use of land-based mechanical removal techniques would likely not be feasible in such areas. These unstable bank conditions primarily exist in the former impoundment areas and removal of submerged sediment adjacent to these areas will (regardless of removal technique) worsen the stability of the banks. In addition, the bank areas in the former impoundment areas are a significant and ongoing source of PCB to the river and must be considered in the remedial process, independent of the removal of the submerged sediment. The remaining bank areas of the river (i.e., outside the current and former impoundments) are generally more stable and do not contain significant PCB-containing sediment.

Although only present along 2% of the river banks, the removal of sediment at the toe of existing structures (i.e., bulkheads, sheetpiles, riprap banks, boat launching areas, etc.) may present a concern to the stability of these structures and caution would have to be exercised during this process. The construction history, detailed plans, and options for ensuring their long-term stability would be considered during the development of the final design for a dredging project. In the former impoundment areas, some bank stabilization work would be required to prevent PCB-containing sediment from eroding back into the river, with or without removal of the submerged sediment from the river.

2.1.5 Shoreline Access

Access to the river is generally a function of land use, topography, and vegetation. Based on a review of the aerial photographs of the Site presented in Figures 2 through 9, and field observations, land use is varied along the Kalamazoo River. However, there are large portions of the floodplain that are undeveloped and support single uses including agricultural or forested land. The topography and vegetation are also mixed and are often related to land use as well. The development of the removal alternative required a more definitive understanding of shoreline access. To gather this data, a site reconnaissance was conducted and the observations regarding access were recorded. The location of these observations and areas of the river that may be difficult to access are identified on Figures 1 through 8 within Appendix A. A description of access on a per river-mile basis is also included in Table 2 within this appendix. The observations indicate that access points exist along many areas of the river, yet there are stretches of the river up to three miles in length where no clear access exists. In addition, many of these access points are limited in terms of their overall available area and may provide enough space for launching equipment to the river, but are not large enough to be used as a construction support zone or sediment transfer station. Given these limitations, a reduced number of potential access locations (i.e., 15) were identified on Figures 2 through 9. In summary, access along the river:

- Is potentially available in many locations;
- Is not present along several stretches up to three miles in length;
- Is limited in size in many areas by physical features; and
- Would limit certain sediment removal and transportation approaches.

These limitations were considered in evaluating the approach to remove (and transport) the sediment given the potential constraint that access can have on the implementability of a remedial alternative.

2.2 Sediment Removal Approach

The development of a sediment removal alternative for the Kalamazoo River began with the selection of a general removal approach, from two available options. The first approach considered included dredging to remove the submerged sediment from the river in "the wet." The second approach includes hydraulic isolation of the river sediment, followed by excavation, or removal in "the dry." Based on the effectiveness, implementability, and relative costs of these approaches, removal in "the wet" using dredging equipment was selected for the submerged sediment. The rationale for selecting removal in the wet as the approach for the submerged sediment is further described below.

2.2.1 Removal in the Wet

Removing the submerged sediment through the water column (in the wet) using hydraulic and/or mechanical means would be extremely challenging and would include dredging approximately 16 million cy of PCB-containing sediment from the Kalamazoo River. The scale of such a project far exceeds any environmental dredging project that has been conducted to date including both the length of the river and the volume of sediment that would be removed.

The effectiveness of sediment removal operations (in the wet or the dry) is highly questionable given the ability of available construction techniques to reduce surficial sediment PCB concentrations to a target residual PCB concentration following dredging. The results of surface sediment samples obtained prior to and following dredging for the 13 projects where complete pre- and post-dredging data sets were available are presented in Table 3 and demonstrate this difficulty. In summary, at median effectiveness, dredging only reduced the surface sediment PCB concentrations by 73%. Note that the United States Environmental Protection Agency (USEPA) recently announced that additional data indicate post-dredging concentrations at Manistique Harbor averaged less than had been seen in previous sampling efforts. While this new data has been included in this table and discussion, it was not possible to include this information in the Supplement to the Kalamazoo River RI/FS, specifically in the KALSIM evaluation.
The inability of dredging in the wet to achieve specific concentration-based goals is the result of several factors including:

- Incomplete spatial coverage in the dredged areas due the creation of windrows and furrows between the swaths of a hydraulic dredge, or cratering of the sediment from the action of a mechanical dredge;
- Accessibility of sediment located in shallow areas where the dredging equipment can not effectively operate, adjacent to or under boulders and debris, or resting on an irregular hardpan or bedrock bottom;
- Performing work underwater that is out of sight of the equipment operator; and
- Resuspension and loss of sediment from the dredging equipment coupled with subsequent downstream transport and redeposition of the material.

In terms of implementability; debris, access, bank stability, and shallow water are the primary challenges for dredging in the Kalamazoo River. Individually, these constraints would not prevent a remedial alternative from being implemented. Rather, they reduce productivity and further limit the effectiveness of dredging. However, when viewed together, these factors could severely limit the effectiveness of the project and would greatly limit the productivity of removal operations. Additionally, this loss of productivity results in a longer construction schedule, and increasing the number of dredges to accelerate schedule could result in increased releases of PCB to the water column.

2.2.2 Removal in the Dry

Removing the submerged sediment in the dry would include blocking off large portions of the river with sheetpiling or other structures such as portable dams or earthen berms to facilitate excavation. In addition to the release of PCB-containing sediment associated with construction equipment required to install the water barriers, dredging of PCB-containing sediment may also be required to provide sufficient water depth for the construction equipment to operate. Once dewatering of the excavation area was complete, the submerged sediment would be removed using a combination of backhoes, bulldozers, and front-end loaders. In some areas of the river, the sediment would be moved from the excavation areas to temporary staging areas with low-ground-pressure vehicles. This process would facilitate subsequent transfer to over-the-road trucks for transportation to a disposal facility. The dewatered sediment areas would also require constant withdrawal and treatment of river water and groundwater to keep the area dry enough to allow equipment to operate. These waters could enter the excavation area through the sheetpiling and through groundwater infiltration. Due to the nature of bed materials throughout the watershed, the quantity of water entering such excavation areas could be very large. During the removal of PCB-containing sediment at the Ruck Pond Site in Wisconsin, infiltration of water into the excavation area was problematic, increasing implementation time and costs, and reducing effectiveness. The reported unit cost for dry excavation of PCB-containing sediment at Ruck Pond was approximately \$1,200 per cubic meter (m^3) (USEPA, 1998a). Alternative approaches have been tried to stabilize wet sediment that is being excavated in the dry. At the Pine River, Michigan site the addition of a stabilization agent (e.g., lime) in-situ occurred prior to excavation. While potentially effective in providing a drier sediment to work with, this step increases the removal cost and results in an increased cost for transportation and disposal as the addition of reagents can increase the overall volume and weight of sediment. It is important to note that even with the addition of in-situ stabilization agents at the Pine River in Michigan, water was still being removed and treated from areas that had been dewatered to facilitate excavation in the dry (USEPA, 2000).

The results of sediment remediation projects conducted in the dry have not demonstrated a clearly greater level of effectiveness as compared to removal through mechanical or hydraulic dredging. While it is clear that both approaches (i.e., removal in the wet or dry) are capable of removing large quantities of bulk sediment, the ability of either approach to achieve target concentrations in surficial sediment following removal is at a minimum questionable, and certainly not without the expenditure of a significant amount of resources. While hydraulically isolating portions of an impoundment such as Lake Allegan is impracticable, blocking-off large reaches of the free run-of-river sections would also have negative impacts from an effectiveness perspective. For example, blocking-off half of the river to facilitate excavation in the dry would alter the hydraulic characteristics of the river. During high flow conditions, this could result in the significant erosion of portions of the floodplain, or erode otherwise stable sediment from portions of the riverbed adjacent to the excavation area. It is also possible for floodwaters to flow back into the excavation area causing significant re-work. Due to these implementation challenges, on balance excavation in the dry does not offer significant performance advantages from an effectiveness perspective over removal in the wet.

In considering implementability, removal in the dry offers an increased ability to excavate sediment with a minimum of debris removal conducted in advance. However, this advantage is more than offset by the additional construction steps (sheet piling, dewatering, water treatment, stabilization, and multiple materials handling steps), the need for river-wide access, and low productivity rates typically associated with removal in the dry. The low productivity rate is evidenced by the 130 cy per day removal rate that is being achieved for portions of the Housatonic River in Pittsfield, Massachusetts where sediment removal in the dry is being conducted in a similar manner, but on a much shorter section of river. Consistent with any removal approach, the sediment would have to be transported to a disposal facility following removal. Given that excavation in the dry would be conducted in a step-wise manner, moving from one side to another, in an upstream to downstream direction in an effort to minimize negative environmental impacts, the project would require multiple locations with appropriate access and space to transfer the sediment into trucks. Based on a review of access points along the river presented in Table 1 in Appendix A and Figures 2 through 9 in this appendix, there are a limited number of locations where sediment could be loaded directly into trucks for transport to a disposal facility following removal. As a result, the sediment removed in the dry would have to be handled more than once between the area of excavation and the loading of the over-the-road trucks for transportation to the disposal facility. An alternative approach using barges to aid in the transportation process would face similar access constraints and multiple sediment handling steps.

There are no apparent cost advantages for removal in the dry and the cost for this technology is also considered as "high" in the remedial technology screening portion of the FS. Cost advantages that may be attributed to an increased ability to address debris, or slightly reduced sediment disposal capacity requirement, could be more then offset by a number of additional construction components required to implement this approach. These additional components all have significant costs associated with their implementation and include:

- Cost associated with hydraulically isolating the river;
- Adding a stabilization agent to the in-situ sediment to facilitate materials handling;
- Pumping and treating water that accumulates in the excavation area;
- Constructing a large number of river access locations to facilitate sediment disposal; and
- Conducting additional materials handling steps due to multiple access locations.

It is important to note that removal in the dry may be appropriate in a limited number of areas along the river including braided channel segments and shallow marsh environment. These areas do not significantly contribute to the overall removal volume of 16 million cy and the specific removal methods would be more appropriately evaluated for these limited areas during the design phase of such a project.

2.2.3 Selected Removal Approach

Removal of the submerged sediment in the wet was selected as the removal method because removal in the dry would not be more effective, is less implementable, and offers no advantages from a cost perspective. While there may be some areas of the river where removal in the dry may be preferable due to shallow water depths or narrow segments of river, the majority of the sediment is associated with the impoundment areas and a single removal approach was selected to represent the majority of sediment in the 52-mile reach of the river.

2.3 Sediment Removal Process Options

The development of the remedial alternative for sediment removal included the evaluation and selection of representative process options for removal, transportation and disposal of the estimated 16 million cy of sediment from the Kalamazoo River. This process examined available dredge equipment to remove the sediment in the wet, the representative method of transporting the sediment to a disposal facility following removal, and the method of sediment disposal. It is important to recognize the interrelationships that exist between these three remedial steps, and how the selection of a process option to complete one step significantly influences the other two. For example, the selection of hydraulic dredging increases the requirement for water treatment as compared to a mechanical dredge, yet pumping a hydraulic slurry to a CDF for dewatering and disposal greatly reduces the implementability challenges and cost for the alternative as a whole. As a result, hydraulic dredging has some advantages if there is space available to facilitate use of a large site-specific CDF. Similarly, if disposal at a permitted off-site commercial landfill were selected as the disposal method instead of site-specific CDFs, gravity dewatering alone would not be sufficient for drying the sediment prior to transport and disposal in a commercial landfill. As a result, disposal in a commercial landfill (if 16 million cy of disposal capacity were available in the area) would result in additional dewatering and water treatment. These issues are further described below.

2.3.1 Dredging Equipment

Three types of wet excavation dredges were identified in the technology screening process that would be potentially applicable to the Kalamazoo River including mechanical, hydraulic, and specialty purpose dredges. While each dredge is designed to remove bulk sediment, each has unique features, operating characteristics; and inherent limitations that when evaluated in conjunction with the site-specific characteristics of a given site, are used to assess the advantages and disadvantages of applying a particular type of equipment. Given the general unavailability and limited operating experience of many of the specialty purpose dredges, they were not carried forward in the technology screening with the exception of an amphibious type dredge which would only be used as a supplement to hydraulic or mechanical dredges, and only in limited areas where access was extremely difficult and quantities of sediment to be removed were small. Despite the potential limitations in availability and operating experience, this dredge was retained for future consideration due to its potential application in shallow water areas that are otherwise not accessible by other dredging equipment. This left mechanical and hydraulic dredging as the available process options for removing the submerged sediment in the wet.

In assessing these two dredges, several factors were considered including the effectiveness of removal, sediment resuspension and disturbance to the water column, productivity (removal rate), water depth, ability to handle debris, commercial availability, and other site-related features such as restrictions due to bridges and dams. Of these, sediment resuspension was a primary factor as it directly influences removal effectiveness and potential water column impacts. For example, the lower the resuspension rate, the less sediment that will be moving away from the point of dredging and could settle in another area of the river. This sediment has the potential to settle out elsewhere in the river. Even conducting the operations within silt curtains will not eliminate the impacts of sediment resuspension as there is often movement beneath the curtains and the migration of dissolved PCB through the curtain itself. Two often overlooked features of working within silt curtains include the redistribution of PCB-containing sediment within the confines of the curtain area during dredging, and the high level of sediment redistribution that occurs when the silt curtains are moved. For example, the difficulties of working within silt curtains and the PCB releases resulting from moving them caused the USEPA to abandon their use during dredging at the New Bedford Harbor Superfund Site (USEPA, 1997). The USEPA abandoned them at Manistique Harbor as well.

In comparing the two dredge types, hydraulic dredging is generally considered to resuspend less sediment than a mechanical dredge. During a demonstration study in Calumet Harbor in 1985, the United States Army Corps of Engineers (USACE) tested two hydraulic dredges (cutterhead and matchbox) and a mechanical dredge to evaluate sediment releases during dredging. The results of this study concluded that higher levels of sediment resuspension were associated with the mechanical dredge, and that the hydraulic dredge only impacted the lower portion of the water column. This was in contrast to the mechanical dredge that affected the entire depth of the water column (Hayes et al, 1988). The difference in the degree of sediment resuspension between mechanical and hydraulic dredges is also recognized in the USEPA's *Handbook for Remediation of Contaminated Sediment*, dated April 1991, where an advantage for hydraulic dredging is limited sediment resuspension and a disadvantage for mechanical dredging is the "potential for large amounts of sediment resuspension". As previously discussed in Section 2.1.3, debris can be particularly problematic for mechanical dredges, even if a water-tight clamshell bucket is used, as debris can prevent the bucket from closing completely, and as a result, the sediment will empty out of the bucket as it is lifted through the water column.

How dredging equipment is operated can have a dramatic effect on sediment resuspension. For mechanical dredges, reducing the speed at which the bucket is raised and lowered through the water column can reduce sediment resuspension, however implementing such an action has the effect of increasing bucket cycle time and lengthening total project duration. For a hydraulic dredge, the key parameters controlling resuspension rates are cutterhead speed, swing speed, depth of burial of the cutterhead, and the pumping rate. For either dredge, the net impact of environmental dredging operations is to slow down productivity in terms of cubic yards of sediment removed per day. In fact "production rates may be deliberately reduced to minimize sediment resuspension" (USEPA, 1994). When conducted under the appropriate operating conditions, hydraulic dredging will typically release less PCB to the water column than a mechanical dredge (USEPA, 1994). As a result, a mechanical dredge is expected to be less effective than a hydraulic dredge in reducing surficial sediment PCB concentrations (i.e., long-term effectiveness), and would also result in higher levels of suspended-sediment PCB in the water column (i.e., short-term effectiveness). In addition, the significant level of debris present throughout the river including large areas in Lake Allegan that contain trees and stumps would further increase the performance gap between hydraulic and mechanical dredges in this setting. The effectiveness of sediment removal is discussed in more detail below in Section 2.3.2.

Based on a combination of the physical characteristics of the river and the distribution of PCB over the 52-mile reach of the river, hydraulic dredging is appears to be the best removal approach for the Kalamazoo River. The shallow water depths, debris, and access limit the application of mechanical dredging as a removal method in many areas of the river. Removing bulk sediment from shallow water areas of the river is currently expected to be more effectively accomplished using a shallow-draft hydraulic dredge, starting in areas with deeper water and gradually working into shallow water areas. This same approach would be extremely difficult to implement with a mechanical dredge given the minimum water depth required for the support equipment, including a barge for the dredge plant and the scows and work-boats required to transport the sediment that has been removed.

Physical barriers and limited access along the river would require multiple handling steps for sediment removed with a mechanical dredge. This is in contrast to hydraulic dredging which could pump the dredged material slurry directly to a CDF constructed along the riverbank. It is important to note the critical link between the method of removal (hydraulic dredge) and the disposal method (site-specific CDFs). If disposal in site-specific CDFs was not viable, the advantage of hydraulic dredging to transport the material, given the access constraints and the ability of CDFs to facilitate cost effective dewatering, would greatly alter the cost and require evaluation of this approach.

2.3.2 Effectiveness of Removal

The effectiveness of using dredging equipment to remove sediment from a waterbody can be measured using a variety of methods, goals, or targets. For example, the ability to remove sediments to a specific depth or elevation can be a goal, which can be evaluated by performing bathymetric soundings prior to the initiation of dredging activities, and then using additional bathymetry after the completion of removal passes, or cuts, made by the dredging equipment, to determine if any sediments remain above the target elevation. This process, which is the main method used for determining the success of navigation maintenance dredging projects, can be repeated until the target goal is met.

When dredging equipment is being used to remove sediment from a waterbody because the sediment contains an undesired concentration of a constituent of concern, such as PCB in the Kalamazoo River system, it is more appropriate to use measurement of the constituent concentration in the surficial sediment following dredging as the primary indicator of goal achievement. For the Kalamazoo River, this would be levels of risk reduction achieved through lowering PCB concentrations in fish. It is reasonable to assume that PCB concentrations in the sediment following removal can be used as an indirect measure to estimate the effectiveness of a given alternative as discussed in the FS.

Given the limitations of dredging equipment to remove all sediment from the bottom of a waterbody, dredging will inevitably leave behind a residual surface layer containing PCB, sometimes at concentrations higher than currently exists. This phenomenon has been observed at several dredging sites, including the Grasse River (New York), New Bedford Harbor (Massachusetts), General Motors- Massena (New York), Sheboygan River and Harbor (Wisconsin), Ruck Pond (Wisconsin), and at the Fox River Deposit N and SMU 56/57 projects (Wisconsin). Additionally, the USACE has stated that "no existing dredge type is capable of dredging a thin surficial layer of contaminated material without leaving behind a portion of that layer and/or mixing a portion of the surficial layer with underlying clean sediment" (Palermo, 1991). Therefore, even though a dredge may in theory be capable of removing substantial volumes of sediment and associated PCB mass, the sediments which the dredge is not capable of removing that are resuspended and eventually settle, or that are mixed with underlying sediment, will remain.

In order to evaluate the effectiveness of dredging on the reduction of PCB concentrations in surface sediments, a review of sites comparable or relevant to the Site was conducted. The sites were selected where sediment was dredged due to elevated concentrations of PCB, and where pre- and post-dredging average surface sediment PCB concentrations were reported. Only sites where dredging was conducted under wet conditions with a hydraulic dredge are included. These sites are summarized in Table 3 and show that where adequate data are available, the ability of dredging to achieve low residual levels of PCB in sediment is quite limited. To provide the best possible understanding of how effective dredging would be in reducing PCB concentrations in Kalamazoo River sediments, the table includes the percentage reduction of surficial sediment PCB concentrations, and median and percentile values. Table 3 shows that the percentage reduction in PCB concentrations measured at other sites ranges from over 98% reduction, to several examples where the PCB concentrations have increased as much as 75% (shown as a -75% reduction) as a direct result of dredging.

The best method for determining the true effectiveness of a cutterhead hydraulic dredge operating in the Kalamazoo River would be to collect field data from such equipment as it was operated at the Site. This type of data is typically collected during a pilot-scale demonstration or interim remedial action at a site. Without such data, the effectiveness can be evaluated by considering a range of reasonably expected values for the reduction in surficial sediment PCB concentrations, using the data presented in Table 3.

Dredges are not capable of measuring concentrations of constituents of concern at the dredgehead, and therefore cannot be operated such that they are used to only remove sediments containing PCB. Instead, the dredge operator must be told to remove sediments above a certain elevation, or down to a certain depth. Therefore, removal of sediments in order to reduce the surficial sediment PCB concentrations to below a specific clean up value, or to remove all sediments containing PCB above a specific clean up value, requires the establishment of a target elevation, or depth of removal, that the dredging equipment will be attempting to reach. After achievement of the target elevation is shown through collection of bathymetric information from the site, samples of the surficial sediments can be collected and analyzed to determine if PCB concentrations have been reduced below the clean up level.

Since dredges have inherent limitations in the their ability to remove sediments from the bottom of a waterway (as discussed in Appendix D), it is common practice when performing sediment removal with dredging equipment to address these limitations through a combination of two steps: 1) by establishing target dredging depths beyond the expected extent of PCB presence and 2) by performing additional dredging operations, or passes, in an attempt to reduce surficial sediment PCB concentrations to the target PCB concentration. As discussed in Section 2.1.1 of this appendix, the sediment volume for the removal alternatives was developed using this approach (i.e., an initial pass six inches below the maximum depth where PCB had been detected followed by a second six-inch clean-up pass). However, this approach (and hence schedule to implement and the estimated cost) did not include the possibility for additional clean-up passes beyond the two-step process if the results of post-removal samples indicates that the target sediment PCB concentration was not achieved. There is a strong possibility that two dredge passes will not achieve the target sediment PCB concentration based on the experience from projects described in Appendix D. In many cases, these projects continued to conduct multiple dredging passes, or in other cases abandoned dredging and implemented a sediment cap as a means of achieving the desired level of risk reduction despite having removed significant quantities of sediment.

2.3.3 Losses During Removal

Several different theoretical and bench-top methods are available for developing predictions of losses from dredging equipment during the removal process. However, projects of this magnitude typically use site-specific pilot-scale studies using full-scale operational equipment to develop loss rates. These pilot-scale studies are also conducted to evaluate the performance of different dredges and identify the appropriate operational parameters to minimize PCB release during dredging. For example, USEPA conducted similar studies during the FS for the New Bedford Harbor Superfund Site where the potential remedial volume was on the order of 1 million cy of PCB-containing sediment. As mentioned above, these studies are also typically used to determine the optimal equipment and operational parameters for dredging. For hydraulic dredges, cutterhead speed, swing speed and degree of burial are critical operational parameters.

Since site-specific release data were not available, sediment release data from another site were used to estimate the movement of PCB-containing sediment away from the point of dredging. The process of evaluating these releases included using the site-specific sediment data for the concentration of PCB assumed to be associated with the suspended sediment moving away from the dredge, and a range of suspended sediment release rates based on a sediment removal project conducted at Lavaca Bay (Wu, 2000). At Lavaca Bay loss rates of sediment resuspended and carried away from the dredging equipment generally ranged from 0.01 to 0.1 kg/sec. Given this and the experience of other environmental dredging projects described in Appendix D, PCB loss during removal is considered a potential risk and care should be taken to:

- Minimize the number of dredges operating in parallel;
- Operate the dredges in an upstream to downstream direction;
- Place operational control on dredging relative to allowable increases in suspended sediment and water column PCB concentrations; and
- Include the use of silt curtains.

It is important to note that despite these actions, PCB will still migrate away from the point of dredging where multiple passes and capping may still be required to achieve the desired level of risk reduction.

While dredging operations would be conducted as reasonably practical to control resuspended sediment losses, the sediment dredging production rates assumed here, and which are necessary for the project to the implementable, cannot be achieved without the loss of some resuspended sediment to downstream areas. Furthermore, the loss of dissolved-phase PCB is inherently less controllable than particulate phase losses. Dissolved phase PCB losses would originate from:

- Desorption from resuspended sediment;
- Desorption from more highly contaminated bed sediments exposed within the areas being dredged; and
- Liberation of sediment pore waters as the sediment bed is broken up by the mechanical actions of the debris clearing and dredging operations.

The challenge for dredging in attempting to achieve RRO 2 is that it would attempt to reduce annual transport rates (approximately 26 kg/yr in 1994) that are a very small and diminishing fraction of the total inventory (26,000 kg) in the channel sediments that would be dredged. Even small percentage losses of that inventory during dredging operations will substantially increase transport during implementation of the remedy. It can be seen that even losses as small as 1 percent[1] over 25 years could cause increased transport of the magnitude of transport measured during the RI [(0.01 x 26,000 kg)/25 years or approximately 10 kg/yr).]

2.3.4 Productivity

Removal of PCB-containing sediment from the Kalamazoo River would include dredging approximately 16 million cy of sediment from depths ranging from 2 to 5½ feet. The removal operations would take place over a 52 mile length of the river and include many areas with shallow water and significant debris. A review of the projects summarized in Appendix D indicates that no dredging project of this size has ever been executed as a remedial alternative for PCB-containing sediment. In order to estimate the sediment removal rate for this project, productivity, in terms of cy/day of in-place sediment removed, was developed using information from similar projects. These projects were chosen as relevant examples for comparison to the type of dredging effort being evaluated for the Kalamazoo River because they share several of the following characteristics:

- Utilized a small- to medium-sized hydraulic dredge;
- Processed the associated large volumes of water through several treatment steps including final polishing with activated carbon;
- Focus on PCB as the main constituent of concern; and
- Placed restrictions on dredge operations in an attempt to minimize resuspension.

The most recent of these projects for which documentation is readily available was the first portion of the Fox River SMU 56/57 demonstration project where a production rate of approximately 60 cy/hour was achieved with a 10-inch

[1] Monitoring of PCB losses from two recent dredging demonstration projects on the Fox River in Wisconsin showed increased PCB transport downstream from the project areas to be approximately 3.5 14 percent of the PCB mass removed (BBL, 2000a; FRRAT, 2000).

dredge. Using this production rate and 10 hours of productive dredging time per day, the estimated production rate for the non-Lake Allegan portions of the river is approximately 600 cy/day. To get 10 hours of actual production dredging per working day, it was assumed that dredging operations would be conducted on a 24-hour per day basis. To maximize production, dredging would be conducted 6 days per week, 10 months per year. For Lake Allegan, the use of two larger 18-inch dredges working in parallel was assumed with a combined removal rate of 2,000 cy per day based on the same operational period (24 hours per day, 6 days per week, 10 months per year). The 60 cy/hr production rate is consistent with the lower end of the operating characteristics for a 10-to-12-inch dredge as presented in Table 4-6 of USEPA (1994), and the lower end of the production rates for a 10-inch dredge presented in USACE (1983). In selecting the lower end it is important to note that these production rates are, by in large, reflective of navigational dredging operations that differ significantly in their productivity (schedule and cost) compared to environmental dredging projects.

To minimize the overall schedule, it was assumed that a maximum of three dredge operations (four dredges including the two dredges working in parallel in Lake Allegan) would proceed in parallel, with the final dredging pass completed in an upstream to downstream direction. Even with the 24 hr/day operations and multiple dredges operating at once, the estimated schedule to complete the dredging is over 24 years. Again, this is due to the large volume of sediment being dredged, coupled with the low productivity typically associated with environmental dredging projects (e.g., at New Bedford Harbor, the USEPA is projecting six to eight years of dredging to remove 450,000 cy of PCB-containing sediment [USEPA, 1998b]).

2.4 Dredged Material Transportation

As discussed earlier in this appendix, the method of sediment transportation will be greatly influenced by the sediment removal method, in this case hydraulic dredging. Based on the remedial technologies carried through the screening process in Section 3 of the FS, there are two primary methods that could be used to transport hydraulically-dredged sediment to a disposal facility such as a commercial landfill or CDF. The first method includes pumping the dredged material directly as a slurry to the CDFs using a series of booster pumps. The maximum range of pumping using a series of booster pump stations is on the order of 10 miles. As such, this pumping distance will require at least three CDFs to accommodate the sediment removed over the 52 miles of river that comprise this site. The second method includes pumping the dredged material slurry to a dewatering area, where the sediment would be dewatered using a combination of gravity settling and/or mechanical presses (such as a plate and frame assembly). Once dewatered, the sediment could be transported to the disposal facility.

Given that a CDF can be used as both a sediment dewatering and sediment disposal facility, the selected process option for sediment transportation is pumping the sediment to a disposal site-specific facility (assumes a CDF will be used for sediment disposal as well). There would be no reason to dewater sediment mechanically if a CDF was used for disposal. If an alternative disposal method was selected, there would be significant costs associated with dewatering and additional water treatment that would have to be factored into the development of the alternative as a whole and as such, the mode of transportation would have to be revisited.

2.5 Dredged Material Disposal

There are several disposal options available for the sediment that were carried through the screening process in the FS. However, treatment of the sediment prior to disposal was not selected as a process option as it is neither necessary, nor practicable given the PCB concentrations and volume of sediment under consideration (16 million cy). The volume of sediment also presents a limitation in terms of the availability of commercial disposal facilities in proximity to the Site. Given these factors and the ability of a CDF to also dewater the sediment, site-specific CDFs were selected as the representative process option for disposal of the sediment. A minimum of three facilities would be required due the maximum distance that a dredged material slurry can reasonably be pumped. These facilities would be CDFs constructed along the banks of the river and provide effective isolation of the sediment from the environment. The use of CDFs is certainly more implementable and less costly than using local commercial disposal facilities.

Both the submerged and exposed sediment would be placed in CDFs specifically constructed for this project. Given the large amount of space required for the disposal (over 1,000 acres in total) the CDFs would likely be constructed in areas that are currently farmland. CDFs would also be relatively easy to construct in these areas given the abundance of open land, as well as the general lack of wetland areas and the stable foundation soils typically present. However, implementability relative to obtaining these large tracts of land from private parties for this use may be problematic.

2.6 Residuals Management

The process option selected for treatment of the water generated in the CDFs includes several steps including flocculation, enhanced sedimentation, dual media filtration, and two-stage polishing with activated carbon absorption. The debris that is removed from the river prior to dredging could potentially be placed in the site-specific CDFs, depending on the allowable design criteria. If a CDF was not considered to be a viable means of disposal, this material would have to be transported to a commercial landfill for disposal, and may require some level of sediment removal as an initial step to facilitate disposal.

3.0 Description Of Removal Alternative

This section of the appendix provides a general description and estimated costs for the removal alternative developed for the Kalamazoo River FS.

3.1 River-Wide Dredging of the Submerged Sediment with Upland Confined Disposal, Bank Stabilization in the Former Impoundments, Institutional Controls, and Monitoring

3.1.1 General Description

This remedial alternative (Alternative 5 in the Kalamazoo River FS) includes removal of PCB-containing submerged sediment at the Site with a hydraulic dredge and pumping the dredged material slurry to one of three CDFs constructed on upland areas adjacent to the river. The size of CDFs necessary to contain the dredged material generated during dredging ranges from 135 to over 770 acres. These CDFs would serve two purposes including a sedimentation basin to separate sediment solids from the dredged material slurry that is pumped to the CDF, and to permanently isolate the PCB-containing dredged material from the environment. Following completion of dredging, the dredged material within the CDFs would be allowed to consolidate for a period of three to five years to facilitate placement of a long-term cap or cover. The large quantity of decanted carriage water generated during the dredging process would be collected from the CDFs and treated prior to discharge to the Kalamazoo River and Lake Allegan. The unit process operations used for treatment of the water include flocculation, sedimentation, dual-media filtration, and two-stage activated carbon adsorption. Water treatment facilities would be constructed adjacent to each of the three CDFs to minimize the number of the water treatment facilities and per gallon treatment costs. This approach also minimizes the overall distance that overflow water from the CDF would need to be pumped prior to treatment and the number and lengths of pipe required to support dredging and water treatment operations. Despite the efforts to minimize the capacity of the water treatment facilities, the three facilities would range from 3 million gallons per day (MGD) in the upper reaches of the river, to 20 MGD serving a CDF adjacent to Lake Allegan. Treatment plant operations would also include monitoring the discharge effluent to ensure compliance with applicable standards. Stabilization of the former impoundment banks, as described in Alternative 3 of the Feasibility Study, would also be implemented after dredging to mitigate the ongoing erosion of PCB-containing sediments from the bank areas into the river. Additional details for this alternative are provided in Section 4.9 of the FS.

3.1.2 Estimated Cost

The estimated cost to dredge and dispose of approximately 16,240,000 cy of sediment from the Kalamazoo River is $2.6 billion dollars. The net present worth (NPW) cost for this project over a 28-year design and construction period is $840 million dollars. The specific details for this cost estimate are presented in Tables 4 and 4.1, which include:

- Construction of the CDFs and water treatment facilities;
- Operation of the dredges, CDFs and water treatment facilities;
- Annual costs for monitoring;
- Total and NPW costs; and
- Notes and assumptions used to develop the cost estimates.

The estimated cost also reflects division of the River into three segments (A, B, and C) to correspond to the three CDFs that would be required to support this project. For each of these segments, the cost estimate table provides the duration in years used to develop the NPW costs.

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Tables

BLASLAND, BOUCK & LEE, INC.
engineers & scientists

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
DREDGING DEPTHS AND VOLUMES BY RIVER REACH

River Reach	First-Pass Dredged Depth (in)	First-Pass Dredged Volume (cy)	Second-Pass 6-in Overdepth Volume (cy)	Total Dredged Volume (cy)
Morrow Dam to Portage Creek	42	476,000	68,000	544,000
Portage Creek to Main Street, Plainwell	18-30	1,000,000	267,000	1,270,000
Main Street, Plainwell to Plainwell Dam	30	232,000	39,000	271,000
Plainwell Dam to Otsego City Dam	42	531,000	74,000	605,000
Otsego City Dam to Otsego Dam	18-60	481,000	64,000	545,000
Otsego Dam to Trowbridge Dam	18-42	705,000	97,000	802,000
Trowbridge Dam to Allegan City Line	30	694,000	139,000	833,000
Allegan City Line to Allegan City Dam	42	633,000	90,000	723,000
Allegan City Dam to Lake Allegan Dam	24-36	9,115,000	1,534,000	10,649,000
Total (rounded)		13,870,000	2,372,000	16,242,000

TABLE 2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
KALAMAZOO RIVER - DREDGING DEPTH SUMMARY AND AVERAGE STREAM VELOCITIES
KALAMAZOO TO LAKE ALLEGAN

River Segment		Segment Length (miles)	Transect	Date Collected	Water Depth[1] Range (feet)	Water Depth[1] Average (feet)	Width (feet)	Proposed Dredging Depth (feet)	Available Depth for Barge Operations[2] (feet)	Stream Velocity Simple Average (feet/sec)
A1	Morrow Dam to Portage Creek Confluence	4.8	KPT1	8/9/93	1.0 - 3.0	2.1	214	4	6.1	1.56
			KPT2	8/10/93	1.3 - 5.1	3.3	160	4	7.3	
			KPT3	8/10/93	1.2 - 5.3	3.1	184	4	7.1	
			KPT4	8/10/93	1.8 - 4.0	2.8	183	4	6.8	
			KPT5	8/10/93	2.0 - 2.9	2.4	188	4	6.4	1.78
			KPT6	8/11/93	1.5 - 3.4	2.3	184	4	6.3	
			KPT7	8/11/93	1.3 - 3.2	2.1	178	4	6.1	
			KPT8	8/11/93	1.3 - 4.2	2.6	177	4	6.6	
			KPT9	8/12/93	0.8 - 3.2	2.0	148	4	6.0	1.8
			KPT10	8/12/93	0.8 - 3.2	2.0	187	4	6.0	
			KPT11	8/12/93	0.4 - 4.2	1.2	342	4	5.2	
			KPT12	8/13/93	2.1 - 4.1	3.1	145	4	7.1	
			KPT13	8/13/93	0.8 - 4.3	2.6	180	4	6.6	1.37
			KPT14	8/16/93	1.5 - 4.2	3.0	472	4	7.0	
			KPT15	8/16/93	2.1 - 5.3	3.5	124	4	7.5	2.17
			KPT16	8/17/93	1.8 - 7.2	5.4	92	4	9.4	
			KPT17	8/17/93	0.9 - 6.4	4.5	128	4	8.5	
			KPT18	8/17/93	2.7 - 3.7	3.3	107	4	7.3	
			KPT19	8/18/93	2.0 - 5.5	4.1	160	4	8.1	0.56
			KPT20	8/18/93	1.8 - 5.3	4.3	155	4	8.3	
A2 (a)	Portage Creek Confluence to north of G Avenue	4.0	KPT21	8/18/93	1.8 - 7.2	4.6	143	3	7.6	
			KPT22	8/18/93	2.2 - 8.1	6.1	141	3	9.1	
			KPT23	8/19/93	2.5 - 10.7	7.9	154	3	10.9	0.47
			KPT24	8/19/93	1.2 - 3.0	2.6	200	3	5.6	
			KPT25	8/19/93	1.2 - 5.1	3.1	165	3	6.1	
			KPT26	8/24/93	1.3 - 4.1	2.3	131	3	5.3	1.1
			KPT27	8/24/93	0.6 - 4.0	2.5	272	3	5.5	
			KPT28	8/24/93	0.6 - 2.9	2.2	243	3	5.2	
			KPT29	8/25/93	2.6 -4.9	4.1	183	3	7.1	

See notes on page 7

TABLE 2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
KALAMAZOO RIVER - DREDGING DEPTH SUMMARY AND AVERAGE STREAM VELOCITIES
KALAMAZOO TO LAKE ALLEGAN

River Segment	Segment Length (miles)	Transect	Date Collected	Water Depth[1] Range (feet)	Water Depth[1] Average (feet)	Width (feet)	Proposed Dredging Depth (feet)	Available Depth for Barge Operations[2] (feet)	Stream Velocity Simple Average (feet/sec)
A2 (b) North of G Avenue to B Avenue	5.0	KPT30	8/25/93	1.2 - 3.5	2.3	138	2	4.3	
		KPT31	8/25/93	2.8 - 5.3	4.2	151	2	6.2	1.38
		KPT32	8/25/93	1.2 - 3.5	2.0	110	2	4.0	
		KPT33	8/26/93	2.2 - 3.6	3.1	205	2	5.1	
		KPT34	8/26/93	2.1 - 4.0	2.9	294	2	4.9	
		KPT35	8/26/93	1.6 - 2.8	2.3	354	2	4.3	1.56
		KPT36	8/30/93	0.6 - 5.5	3.4	104	2	5.4	
		KPT37	8/30/93	1.7 - 4.0	2.9	140	2	4.9	
		KPT38	8/30/93	1.5 - 4.5	3.1	168	2	5.1	1.43
		KPT39	8/31/93	2.1 - 4.4	3.5	171	2	5.5	
		KPT40	8/31/93	1.0 - 3.4	2.1	260	2	4.1	
		KPT41	8/31/93	1.7 - 5.4	4.2	165	2	6.2	
		KPT42	8/31/93	1.1 - 3.9	2.9	150	2	4.9	1.91
A2 (c) B Avenue to Main Street, Plainwell	5.9	KPT43	9/2/93	3.2 - 5.6	4.2	137	2.5	6.7	
		KPT44	9/2/93	1.4 - 6.9	4.5	150	2.5	7.0	
		KPT45	9/3/93	3.6 - 5.8	5.0	143	2.5	7.5	
		KPT46	9/7/93	1.0 - 6.7	4.4	117	2.5	6.9	2.14
		KPT47	9/7/93	0.8 - 6.3	3.5	84	2.5	6.0	
		KPT48	9/8/93	1.8 - 4.6	3.4	216	2.5	5.9	
		KPT49	9/8/93	1.5 - 7.1	4.7	130	2.5	7.2	
		KPT50	9/8/93	2.2 - 3.6	2.9	125	2.5	5.4	1.39
		KPT51	9/8/93	1.8 - 4.4	3.3	56	2.5	5.8	
		KPT52	9/9/93	1.2 - 4.4	3.0	58	2.5	5.5	
		KPT53	9/9/93	1.3 - 5.5	4.1	91	2.5	6.6	
		KPT54	9/9/93	3.2 - 6.0	4.5	119	2.5	7.0	1.43
		KPT55	9/9/93	1.6 - 3.1	2.4	130	2.5	4.9	2.97

See notes on page 7

TABLE 2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
KALAMAZOO RIVER - DREDGING DEPTH SUMMARY AND AVERAGE STREAM VELOCITIES
KALAMAZOO TO LAKE ALLEGAN

River Segment		Segment Length (miles)	Transect	Date Collected	Water Depth[1] Range (feet)	Water Depth[1] Average (feet)	Width (feet)	Proposed Dredging Depth (feet)	Available Depth for Barge Operations[2] (feet)	Stream Velocity Simple Average (feet/sec)
B	Main Street, Plainwell to Plainwell Dam	1.9	KPT56	9/10/93	1.5 - 5.2	3.2	215	3	6.2	
			KPT57	9/10/93	1.6 - 2.9	2.3	220	3	5.3	2.21
			KPT58	9/10/93	1.7 - 3.2	2.3	242	3	5.3	
			KPT59	9/13/93	1.3 - 4.2	2.7	209	3	5.7	
			KPT60	9/13/93	1.0 - 4.5	3.2	221	3	6.2	
			KPT61	9/14/93	1.7 - 3.0	2.3	265	3	5.3	1 27
			KPT62	9/14/93	0.7 - 3.2	2.3	236	3	5.3	
			KPT63	9/14/93	3.0 - 6.8	4.7	118	3	7.7	
			KPT64	9/14/93	2.8 - 5.1	4.4	154	3	7.4	
			KPT65	9/15/93	2.6 - 7.8	6.3	133	3	9.3	1.34
			KPT66	9/15/93	4.5 - 6.9	5.6	143	3	8.6	
			KPT67	9/15/93	2.7 - 7.3	5.4	210	3	8.4	
C	Plainwell Dam to Otsego City Dam	1.7	KPT68	9/16/93	1.7 - 6.0	3.7	294	4	7.7	1.38
			KPT69	9/16/93	0.3 - 4.7	2.4	302	4	6.4	
			KPT70	9/16/93	1.0 - 7.0	2.3	211	4	6.3	1.25
			KPT71	9/17/93	0.8 - 6.3	3.0	166	4	7.0	
			KPT72	9/17/93	1.5 - 5.5	2.8	109	4	6.8	
			KPT73	9/20/93	1.8 - 3.3	2.5	140	4	6.5	
			KPT74	9/21/93	1.0 - 3.3	1.7	106	4	5.7	0.93
			KPT75	9/21/93	0.8 - 3.8	1.9	613	4	5.9	
			KPT76	9/21/93	1.4 - 3.5	2.4	217	4	6.4	1.9
			KPT77	9/22/93	0.8 - 3.8	2.1	285	4	6.1	
			KPT78	9/22/93	0.6 - 6.4	3.1	216	4	7.1	
			KPT79	9/22/93	0.9 - 4.2	2.6	247	4	6.6	

TABLE 2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
KALAMAZOO RIVER - DREDGING DEPTH SUMMARY AND AVERAGE STREAM VELOCITIES
KALAMAZOO TO LAKE ALLEGAN

River Segment	Segment Length (miles)	Transect	Date Collected	Water Depth[1] Range (feet)	Water Depth[1] Average (feet)	Width (feet)	Proposed Dredging Depth (feet)	Available Depth for Barge Operations[2] (feet)	Stream Velocity Simple Average (feet/sec)
D (a) Otsego City Dam to 19th Street	2.2	KPT80	9/22/93	1.9 - 7.0	3.4	168	2	5.4	2.05
		KPT81	9/27/93	1.3 - 6.2	4.3	160	2	6.3	
		KPT82	9/27/93	0.9 - 4.0	2.5	242	2	4.5	
		KPT83	10/4/93	1.1 - 4.0	2.7	218	2	4.7	
		KPT84	10/4/93	2.2 - 3.4	2.8	178	2	4.8	3.41
		KPT85	10/4/93	2.6 - 6.6	5.1	153	2	7.1	
		KPT86	10/5/93	1.7 - 6.9	4.2	169	2	6.2	
		KPT87	10/5/93	2.1 - 4.3	3.4	187	2	5.4	
		KPT88	10/5/93	2.3 - 5.8	3.7	211	2	5.7	1.56
D (b) 19th Street to Otsego Dam	1.2	KPT89	10/5/93	3.1 - 7.3	4.7	145	5.5	10.2	
		KPT90	10/5/93	2.3 - 5.3	4.4	213	5.5	9.9	
		KPT91	10/6/93	4.1 - 5.5	4.6	181	5.5	10.1	
		KPT92	10/6/93	2.1 - 6.2	3.0	251	5.5	8.5	1.38
		KPT93	10/6/93	0.9 - 5.5	2.8	291	5.5	8.3	
		KPT94	10/6/93	1.7 - 6.8	5.0	231	5.5	10.5	
E (a) Former Trowbridge Impoundment (upper)	2.5	KPT95	10/7/93	0.3 - 6.3	3.4	122	2	5.4	
		KPT96	10/7/93	0.5 - 5.4	3.7	145	2	5.7	2.99
		KPT97	10/7/93	1.7 - 3.7	2.7	199	2	4.7	
		KPT98	10/8/93	1.6 - 5.0	3.5	158	2	5.5	
		KPT99	10/11/93	1.5 - 4.5	3.6	190	2	5.6	
		KPT100	10/11/93	3.0 - 5.3	4.4	195	2	6.4	1.19
		KPT101	10/14/93	2.5 - 9.2	5.7	144	2	7.7	
E (b) Former Trowbridge Impoundment (lower)	2.2	KPT102	10/14/93	0.9 - 5.8	4.1	216	4	8.1	
		KPT103	10/19/93	4.2 - 11.3	8.6	152	4	12.6	
		KPT104	10/19/93	2.9 - 10	7.4	210	4	11.4	1.81
		KPT105	10/20/93	3.2 - 9.5	6.5	185	4	10.5	
		KPT106	10/20/93	2.4 - 8.2	6.3	240	4	10.3	
		KPT107	10/20/93	2.5 - 8.4	5.4	281	4	9.4	
		KPT108	10/21/93	2.4 - 6.3	3.1	814	4	7.1	0.68
		KPT109	10/21/93	3.0 - 11.2	7.2	193	4	11.2	

TABLE 2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
KALAMAZOO RIVER - DREDGING DEPTH SUMMARY AND AVERAGE STREAM VELOCITIES
KALAMAZOO TO LAKE ALLEGAN

River Segment		Segment Length (miles)	Transect	Date Collected	Water Depth[1] Range (feet)	Water Depth[1] Average (feet)	Width (feet)	Proposed Dredging Depth (feet)	Available Depth for Barge Operations[2] (feet)	Stream Velocity Simple Average (feet/sec)
F	Trowbridge Dam to Allegan City Line	7.2	KPT110	10/22/93	3.0 - 5.5	4.3	205	3	7.3	
			KPT111	10/25/93	2.0 - 5.1	3.7	196	3	6.7	
			KPT112	10/25/93	2.3 - 9.2	5.5	145	3	8.5	2.77
			KPT113	10/26/93	2.6 - 6.2	4.3	155	3	7.3	3.3
			KPT114	10/26/93	4.0 - 5.0	4.6	136	3	7.6	
			KPT115	10/26/93	0.6 - 3.6	2.7	97	3	5.7	
			KPT115A	10/26/93	2.3 - 4.1	3.3	55	3	6.3	1.62
			KPT116	10/27/93	2.8 - 4.2	3.3	236	3	6.3	
			KPT117	10/27/93	3.3 - 7.3	4.9	211	3	7.9	
			KPT118	10/27/93	3.3 - 4.8	3.9	301	3	6.9	2.49
			KPT119	10/28/93	1.7 - 10.4	4.7	293	3	7.7	
			KPT120	10/28/93	2.0 - 10.0	5.6	192	3	8.6	
			KPT121	10/28/93	2.2 - 5.3	3.6	232	3	6.6	
			KPT122	10/29/93	1.1 - 7.6	4.1	289	3	7.1	1.81
			KPT123	11/1/93	2.1 - 6.6	4.8	180	3	7.8	
			KPT124	11/1/93	2.2 - 10.4	7.2	147	3	10.2	
			KPT125	11/2/93	1.0 - 6.4	4.2	265	3	7.2	
			KPT126	11/2/93	0.5 - 6.1	3.5	240	3	6.5	1.47
G	Allegan City Line to Allegan City Dam	1.9	KPT127	11/2/93	2.9 - 5.5	4.6	227	4	8.6	
			KPT128	11/3/93	0.0 - 7.4	5.5	170	4	9.5	
			KPT129	11/3/93	0.0 - 7.3	4.3	141	4	8.3	
			KPT130	11/3/93	1.1 - 4.3	3.1	317	4	7.1	1.33
			KPT131	11/4/93	0.1 - 5.6	2.6	221	4	6.6	
			KPT132	11/4/93	1.9 - 13.5	7.4	185	4	11.4	
			KPT133			2.8	386	4	6.8	
			KPT134			2.5	711	4	6.5	
			KPT135			2.4	1650	4	6.4	
			KPT136	3/9/94		2.5	1480	4	6.5	0.58
			KPT137			3.4	1280	4	7.4	
			KPT138			4.1	500	4	8.1	
			KPT139	11/5/93	0.0 - 5.8	3.6	584	4	7.6	

TABLE 2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
KALAMAZOO RIVER - DREDGING DEPTH SUMMARY AND AVERAGE STREAM VELOCITIES
KALAMAZOO TO LAKE ALLEGAN

River Segment	Segment Length (miles)	Transect	Date Collected	Water Depth[1] Range (feet)	Water Depth[1] Average (feet)	Width (feet)	Proposed Dredging Depth (feet)	Available Depth for Barge Operations[2] (feet)	Stream Velocity Simple Average (feet/sec)
H (a) Lake Allegan (upper)	3.1	KPT140	11/9/93	0.8 - 9.9	5.2	167	2.5	7.7	
		KPT141	3/10/94		6.2	175	2.5	8.7	2.6
		KPT142			5.5	315	2.5	8.0	
		KPT143			2.0	1040	2.5	4.5	
H (b) Lake Allegan (lower)	6.7	KPT144							
		KPT145			3.0	835	4	7.0	
		KPT146			7.6	724	4	11.6	
		KPT147	2/4/94	1.0 - 9.6	4.1	860	4	8.1	
		KPT148	2/3/93	0.7 - 7.2	2.8	1306	4	6.8	
		KPT149	2/2/94	2.3 - 10.0	5.9	600	4	9.9	
		KPT150	2/2/94	3.5 - 14.7	8.2	413	4	12.2	
		KPT151	2/1/94	2.3 - 9.0	5.4	813	4	9.4	
		KPT152	2/1/94	1.9 - 7.3	4.1	1892	4	8.1	
		KPT153	1/31/94	5.5 - 8.2	6.5	2665	4	10.5	
		KPT154	1/27/94	7.0 - 9.8	8.4	2786	4	12.4	
		KPT155	1/19/94	9.8 - 11.7	10.9	1965	4	14.9	
		KPT156	1/20/94	3.2 - 16.3	11.3	2200	4	15.3	
		KPT157	1/13/94	3.6 - 12.8	10.5	5299	4	14.5	
		KPT158	1/12/94	10.3 - 14.1	12.3	4430	4	16.3	
		KPT159	1/12/94	8.5 - 19	12.4	3251	4	16.4	

TABLE 2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

KALAMAZOO RIVER - DREDGING DEPTH SUMMARY AND AVERAGE STREAM VELOCITIES KALAMAZOO TO LAKE ALLEGAN

General Notes:

1. Average water depths measurements were obtained for the period between August 1993 and february 1994. Refer to Draft Technical Memorundum 10 (BBL,1994).
2. Available depth for barge operations at a given location is obtained by summing water depth and dredging depth for that location.

Shaded areas indicate areas of concern thereby representing narrow secondary channels, and/or shallow water depths. Refer to "Specific Notes" for details.

Indicates stream velocities that may make silt curtain deployment difficult.

Specific Notes:

1. At transect KPT 11, shallow areas were encountered on both banks. These areas measured approximately a 90 feet section on left bank (looking downstream) with an average water depth of 0.65 feet, and a 250 feet section on the right bank with an average water depth of 0.5 feet.
2. Transect KPT 32 cuts across an oxbow island. The channel impounded by the island is about 30-foot wide with an average water depth of 1.3 feet.
3. Transect KPT 47 cuts across an island. The channel impounded on the right side of the island (looking downstream) is about 50-foot wide with an average water depth of 1.17 feet. Note that the island did not appear on the Fall 1999 aerial photographs.
4. Transects KPT 68 through 79 cut across the Otsego City Dam Impoundment, where the Kalamazoo River is characterized by a braided channels system. Some of the secondary channels range 20 to 40 feet in width with the average water depth ranging between less than 1 foot and 2 feet.
5. At transect KPT 122, a shallow shelf that measured approximately 110 feet in width with an average water depth of 1.3 feet, has formed near the left bank (looking downstream).
6. At transect KPT 126, a shallow shelf that measured approximately 75 feet in width with an average water depth of 0.8 feet, has formed near the right bank (looking downstream).
7. At transect KPT 129, a shallow shelf that measured approximately 75 feet in width with an average water depth of 0.8 feet has formed near the right bank (looking downstream).
8. The river reach between Transects 132 and 135 shows island formations with wide shallow channels between them. Some of these channels appeared to have water depth of about 1 foot (based on June 2000 field visit).
9. The river reach between Transects 142 and 143 also contains island formations. This area would likely have shallow sediment deposits.
10. Transect KPT 148 shows another low energy area where shallow sediment deposits extend for a 500-foot section in the middle of the channel. The average depth in this shallow area was measured at 1 foot.

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
DREDGING EFFECTIVENESS (PCB SITES)

		Pre-Dredging Surficial PCB Sediment Concentration						Post-Dredging Surficial PCB Sediment Concentration						Dredging Effectiveness							
Site	Year Dredged	Pre-Dredge Avg PCB (ppm)	MIN conc (ppm)	MAX conc (ppm)	Depth	n	Year Collected	Post-Dredge Avg PCB (ppm)	MIN conc (ppm)	MAX conc (ppm)	Depth	n	Year Collected	Reduction of AVERAGE	Reduction of MIN	Reduction of MAX	Hydraulic/ Mechanical	# of passes	Cubic Yards Removed	# of Areas Averaged/ Other Notes	References
Duwamish Waterway	1976	4	<1	42	1 ft	26	1976	7	0.2	140	1 ft.	25	1976	-75%		-233%	Hydraulic				Blazevich et al 1977
Fox River Deposit N	1998-99	16	0.8	72	NA	18	1998	9.2	0.9	37	NA	NA	1999 (EPA Report)	43%	-13%	49%	Hydraulic	1	7,160	2 areas (West/East Lobes)	Foth & VanDyke 2000
Fox River SMU 56/57 (4 dredged subunits with multiple passes)	1999	3.5			4 in	4	1999	3.2			4 in	4	Dec 1999-Jan 2000	9%			Hydraulic	multiple *	12,000	4 subunits, cy apprx	BBL, 2000a
Grasse River	1995	518	12	1,780	1 ft.	9	1991, 1993	75	1.1	260	6-8 in.	10	1995	86%	91%	85%	Hydraulic		2,400	1 area See note 1	BBL, 1995
Lake Jarnsjon Sweden	1993-94	8.1	0.4	31	1.3 ft	12	1991	0.13	0.01	2	20 cm	54	NA	98%	98%	92%	Hydraulic		200,000		Bremle and Ewald 1995, Bremle et al 1998, Gullbring and Hammar 1993
Manistique River (Harbor)	1996-2000	14	ND	90	3 in	59	1993	19	0.084	390	3 in	28	1999	-36%		-333%	Hydraulic				BBL, 2000b
Manistique River (Harbor)	1996-2000	14	ND	90	3 in	59	1993	9.8					2000	30%			Hydraulic				USEPA, 2000
New Bedford Harbor pilot study (Area 1 surface sediments)	1988-89	230	150	260	6 in	6	1987	66.4	9.3	270	3 in	32	1988-89	71%	94%	-4%	Hydraulic	5	20,800	1 area	USACE, 1990
New Bedford Harbor pilot study (Area 2 surface sediments)	1988-89	380	300	580	6 in	6	1987	5.4	3	10	3 in	16	1988-89	98.6%	99%	98%	Hydraulic	4	9,360	1 area	USACE 1990
Portland General Electric	1990	29		170	NA	29	1988	7		21	NA	6		76%		88%	Hydraulic				CH2M Hill 1991
Shiawassee River (Bowen Rd)	1982	40	0.8	80	NA	9	1977	1.9	ND	6	1 ft	9	1987	95%		93%	Hydraulic		1,805	1.5 river miles	Warzyn, 1992
Shiawassee River (South Branch Study Area)	<1982	24						7.2						70.0%			Hydraulic		2	Only 2 cubic yards removed. For entire depth of sediments (appx 6 in.) avg pre dredge PCB was 540 ppm and post-dredge was 4.2 ppm	Environmental Research Group 1982
St Lawrence River (GM Massena)	1995	548	0.91	8,800	6 in	27	1993	9.2	0.1	91	NA	113	1995	98%		99%	Hydraulic	2 to 6 30 in hot spot	13,800	6 areas	BBLES 1996
Waukegan Harbor (Upper Harbor)	1991-92	144	8	460	NA	15	1977-78, 1990	6.2	3	8	3 in	6	1996	96%	63%	98%	Hydraulic	completed to a designated soil type/elevation	32,000	Post dredging samples taken over four years after dredging	IEPA 1999 Lesnak 1997, Swackhamer and Armstrong, 1988
FINAL MEDIAN EFFECTIVENESS														73%	92%	88%					
10TH PERCENTILE														22%	25%	-233%					
25TH PERCENTILE														33%	70%	22%					
75TH PERCENTILE														96%	97%	96%					
90TH PERCENTILE														98%	98%	98%					

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 5 - DREDGING OF SUBMERGED SEDIMENTS WITH UPLAND CONFINED DISPOSAL

Item No.	Remedial Component	Quantity	Units	Unit Cost	Item Cost
A1	**Construction**				
	Mobilization - 1	1	lump sum	$596,000	$596,000
	General Conditions	1	lump sum	$447,000	$447,000
	Project Insurance	1	lump sum	$298,000	$298,000
	Construction Trailers	24	month	$400	$10,000
	Clearing	20,000	linear foot	$21	$420,000
	Access road construction/restoration	47,000	square yard	$27	$1,269,000
	CDF Land lease or purchase	140	acre	$8,000	$1,120,000
	CDF clearing & grubbing	140	acre	$7,700	$1,078,000
	CDF bedding	217,287	cubic yard	$20	$4,346,000
	CDF exterior dikes	490,309	cubic yard	$15	$7,355,000
	CDF interior dikes	511,643	cubic yard	$15	$7,675,000
	CDF liner, bot & walls	5,866,760	square foot	$0 50	$2,933,000
	CDF piping	1	lump sum	$698,000	$698,000
	CDF monitoring wells	11	well	$1,000	$11,000
	WTF site preparation & paving	24,200	square yard	$25	$605,000
	WTF coagulation/flocculation/sedimentation	1	lump sum	$656,000	$656,000
	WTF multimedia filters	1	lump sum	$474,000	$474,000
	WTF carbon adsorption	1	lump sum	$545,000	$545,000
	WTF control building	1,500	square foot	$70	$105,000
	WTF misc pumps, piping & electrical	1	lump sum	$477,000	$477,000
	SUBTOTAL				$31,118,000
	Engineering/Project Management (8%)				$2,489,000
	Construction Oversight (6%)				$1,867,000
	Contingency (20%)				$6,224,000
				TOTAL (YEARS 2005 - 2005):	$41,698,000
				PRESENT VALUE:	$29,730,000
A1	**Operations**				
	Dredging mobilization - 1	1	lump sum	$2,517,000	$2,517,000
	General Conditions	1	lump sum	$1,887,000	$1,887,000
	Project Insurance	1	lump sum	$1,258,000	$1,258,000
	Construction Trailers	144	month	$400	$58,000
	Dredges, barges, pumps and boats	12	year	$700,726	$8,409,000
	Dredge, boat and pump fuel use	12	year	$654,410	$7,853,000
	Dredge labor	12	year	$1,303,584	$15,643,000
	Dredge pipelines	12	year	$696,960	$8,364,000
	Silt Curtains, reefing and anchoring	12	year	$123,000	$1,476,000
	Turbidity monitoring stations	1	lump sum	$2,888,000	$2,888,000
	Shoreline protection	1	lump sum	$6,083,000	$6,083,000
	Operate CDF - labor	3,327	day	$3,086	$10,268,000
	CDF & WTF maintenance	12	year	$1,294,000	$15,528,000
	WTF chemicals	9,510	m gal	$1,500	$14,264,000
	WTF filter media	9,510	m gal	$200	$1,902,000
	WTF activated carbon	9,510	m gal	$1,860	$17,688,000
	Operate WTF - labor	3,327	day	$4,629	$15,403,000
	SUBTOTAL				$131,489,000
	Engineering/Project Management (5%)				$6,574,000
	Construction Oversight (6%)				$7,889,000
	Contingency (20%)				$26,298,000
				TOTAL (YEARS 2005 - 2016):	$172,250,000
				PRESENT VALUE:	$86,978,000

(See notes on page 7)

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 5 - DREDGING OF SUBMERGED SEDIMENTS WITH UPLAND CONFINED DISPOSAL

Item No.	Remedial Component	Quantity	Units	Unit Cost	Item Cost
A2	**Construction**				
	CDF and WTF mobilization - 2	1	lump sum	$123,000	$123,000
	General Conditions	1	lump sum	$92,000	$92,000
	Project Insurance	1	lump sum	$62,000	$62,000
	Construction Trailers	12	month	$400	$5,000
	Bank stab. & Habitat enhancement - Plainwell	1	lump sum	$4,144,000	$4,144,000
	WTF coagulation/flocculation/sedimentation	1	lump sum	$656,000	$656,000
	WTF multimedia filters	1	lump sum	$474,000	$474,000
	WTF carbon adsorption	1	lump sum	$545,000	$545,000
	WTF misc pumps, piping & electrical	1	lump sum	$335,000	$335,000
	SUBTOTAL				$6,436,000
	Engineering/Project Management (8%)				$515,000
	Construction Oversight (6%)				$386,000
	Contingency (20%)				$1,287,000
				TOTAL (YEARS 2016 - 2016):	$8,624,000
				PRESENT VALUE:	$2,180,000
A2	**Operations**				
	Dredging mobilization - 2	1	lump sum	$483,000	$483,000
	General Conditions	1	lump sum	$362,000	$362,000
	Project Insurance	1	lump sum	$242,000	$242,000
	Construction Trailers	36	month	$400	$14,000
	Dredges, barges, pumps and boats	3	year	$805,351	$2,416,000
	Dredge, boat and pump fuel use	3	year	$1,034,570	$3,104,000
	Dredge labor	3	year	$1,303,584	$3,911,000
	Dredge pipelines	3	year	$760,320	$2,281,000
	Silt Curtains, reefing and anchoring	3	year	$123,000	$369,000
	Turbidity monitoring stations	1	lump sum	$610,000	$610,000
	Shoreline protection	1	lump sum	$1,327,000	$1,327,000
	Operate CDF - labor	726	day	$3,086	$2,241,000
	CDF & WTF maintenance	3	year	$1,395,000	$4,185,000
	WTF chemicals	96	m gal	$1,500	$144,000
	WTF filter media	96	m gal	$200	$19,000
	WTF activated carbon	96	m gal	$1,860	$179,000
	Operate WTF - labor	726	day	$4,629	$3,361,000
	SUBTOTAL				$25,248,000
	Engineering/Project Management (5%)				$1,262,000
	Construction Oversight (6%)				$1,515,000
	Contingency (20%)				$5,050,000
				TOTAL (YEARS 2017 - 2019):	$33,075,000
				PRESENT VALUE:	$9,801,000
A3	**Construction**				
	Mobilization - 3	1	lump sum	$849,000	$849,000
	General Conditions	1	lump sum	$636,000	$636,000
	Project Insurance	1	lump sum	$424,000	$424,000
	Construction Trailers	12	month	$400	$5,000
	Decommission water treat facilities	1	lump sum	$1,949,000	$1,949,000
	CDF top liner	5,866,760	square foot	$0 50	$2 933,000
	CDF cover material	651,862	cubic yard	$25	$16,297,000
	CDF 2% graded cap	849,895	cubic yard	$25	$21,247,000
	SUBTOTAL				$44,340,000
	Engineering/Project Management (8%)				$3,547,000
	Construction Oversight (6%)				$2,660,000
	Contingency (20%)				$8,868,000
				TOTAL (YEARS 2024 - 2024):	$59,415,000
				PRESENT VALUE:	$11,713,000

(See notes on page 7)

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 5 - DREDGING OF SUBMERGED SEDIMENTS WITH UPLAND CONFINED DISPOSAL

Item No.	Remedial Component	Quantity	Units	Unit Cost	Item Cost
B1	**Construction**				
	Mobilization - 1	1	lump sum	$952,000	$952,000
	General Conditions	1	lump sum	$714,000	$714,000
	Project Insurance	1	lump sum	$476,000	$476,000
	Construction Trailers	24	month	$400	$10,000
	Clearing	22,000	linear foot	$21	$462,000
	Access road construction/restoration	52,000	square yard	$27	$1,404,000
	CDF Land lease or purchase	287	acre	$8,000	$2,296,000
	CDF clearing & grubbing	287	acre	$7,700	$2,210,000
	CDF bedding	454,173	cubic yard	$20	$9,083,000
	CDF exterior dikes	711,881	cubic yard	$15	$10,678,000
	CDF interior dikes	733,214	cubic yard	$15	$10,998,000
	CDF liner, bot & walls	12,262,658	square foot	$0.50	$6,131,000
	CDF piping	1	lump sum	$1,459,000	$1,459,000
	CDF monitoring wells	16	well	$1,000	$16,000
	WTF site preparation & paving	24,200	square yard	$25	$605,000
	WTF coagulation/flocculation/sedimentation	1	lump sum	$656,000	$656,000
	WTF multimedia filters	1	lump sum	$474,000	$474,000
	WTF carbon adsorption	1	lump sum	$545,000	$545,000
	WTF control building	1,500	square foot	$70	$105,000
	WTF misc pumps, piping & electrical	1	lump sum	$477,000	$477,000
	SUBTOTAL				$49,751,000
	Engineering/Project Management (8%)				$3,980,000
	Construction Oversight (6%)				$2,985,000
	Contingency (20%)				$9,950,000
				TOTAL (YEARS 2005 - 2005):	$66,666,000
				PRESENT VALUE:	$47,532,000
B1	**Operations**				
	Dredging mobilization - 1	1	lump sum	$4,634,000	$4,634,000
	General Conditions	1	lump sum	$3,476,000	$3,476,000
	Project Insurance	1	lump sum	$2,317,000	$2,317,000
	Construction Trailers	240	month	$400	$96,000
	Dredges, barges, pumps and boats	20	year	$700,726	$14,015,000
	Dredge, boat and pump fuel use	20	year	$654,410	$13,088,000
	Dredge labor	20	year	$1,303,584	$26,072,000
	Dredge pipelines	20	year	$696,960	$13,939,000
	Silt Curtains, reefing and anchoring	20	year	$123,000	$2,460,000
	Turbidity monitoring stations	1	lump sum	$5,166,000	$5,166,000
	Shoreline protection	1	lump sum	$10,819,000	$10,819,000
	Operate CDF - labor	5,918	day	$3,086	$18,262,000
	CDF & WTF maintenance	20	year	$2,061,000	$41,220,000
	WTF chemicals	16,624	m gal	$1,500	$24,936,000
	WTF filter media	16,624	m gal	$200	$3,325,000
	WTF activated carbon	16,624	m gal	$1,860	$30,920,000
	Operate WTF - labor	5,918	day	$4,629	$27,393,000
	SUBTOTAL				$242,138,000
	Engineering/Project Management (5%)				$12,107,000
	Construction Oversight (6%)				$14,528,000
	Contingency (20%)				$48,428,000
				TOTAL (YEARS 2006 - 2025):	$317,201,000
				PRESENT VALUE:	$119,797,000

(See notes on page 7)

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 5 - DREDGING OF SUBMERGED SEDIMENTS WITH UPLAND CONFINED DISPOSAL

Item No.	Remedial Component	Quantity	Units	Unit Cost	Item Cost
B2	**Construction**				
	CDF and WTF mobilization - 2	1	lump sum	$435,000	$435,000
	General Conditions	1	lump sum	$326,000	$326,000
	Project Insurance	1	lump sum	$218,000	$218,000
	Construction Trailers	12	month	$400	$5,000
	Bank stab & habitat enhancement - Otsego	1	lump sum	$5,359,000	$5,359,000
	Bank stab & habitat enhancemt - Trowbridge	1	lump sum	$14,382,000	$14,382,000
	WTF coagulation/flocculation/sedimentation	1	lump sum	$656,000	$656,000
	WTF multimedia filters	1	lump sum	$474,000	$474,000
	WTF carbon adsorption	1	lump sum	$545,000	$545,000
	WTF misc piping & electrical	1	lump sum	$335,000	$335,000
	SUBTOTAL				$22,735,000
	Engineering/Project Management (8%)				$1,819,000
	Construction Oversight (6%)				$1,364,000
	Contingency (20%)				$4,547,000
				TOTAL (YEARS 2022 - 2022):	$30,465,000
				PRESENT VALUE:	$6,455,000
B2	**Operations**				
	Dredging mobilization - 2	1	lump sum	$84,000	$84,000
	General Conditions	1	lump sum	$640,000	$640,000
	Project Insurance	1	lump sum	$427,000	$427,000
	Construction Trailers	36	month	$400	$14,000
	Dredges, barges, pumps and boats	3	year	$805,351	$2,416,000
	Dredge, boat and pump fuel use	3	year	$1,034,570	$3,104,000
	Dredge labor	3	year	$1,303,584	$3,911,000
	Dredge pipelines	3	year	$760,320	$2,281,000
	Silt Curtains, reefing and anchoring	3	year	$123,000	$369,000
	Turbidity monitoring stations	1	lump sum	$762,000	$762,000
	Shoreline protection	1	lump sum	$1,651,000	$1,651,000
	Operate CDF - labor	903	day	$3,086	$2,787,000
	CDF & WTF maintenance	3	year	$2,162,000	$6,486,000
	WTF chemicals	5,312	m gal	$1,500	$7,968,000
	WTF filter media	5,312	m gal	$200	$1,062,000
	WTF activated carbon	5,312	m gal	$1,860	$9,880,000
	Water treatment - second pass	903	day	$4,629	$4,180,000
	SUBTOTAL				$48,022,000
	Engineering/Project Management (5%)				$2,401,000
	Construction Oversight (6%)				$2,881,000
	Contingency (20%)				$9,604,000
				TOTAL (YEARS 2023 - 2025):	$62,908,000
				PRESENT VALUE:	$12,421,000
B3	**Construction**				
	Mobilization - 3	1	lump sum	$2,200,000	$2,200,000
	General Conditions	1	lump sum	$1,650,000	$1,650,000
	Project Insurance	1	lump sum	$1,100,000	$1,100,000
	Construction Trailers	12	month	$400	$5,000
	Decommission water treat facilities	1	lump sum	$1,949,000	$1,949,000
	CDF top liner	12,262,658	square foot	$0 50	$6,131,000
	CDF cover material	1,362,518	cubic yard	$25	$34,063,000
	CDF 2% graded cap	2,713,281	cubic yard	$25	$67,832,000
	SUBTOTAL				$114,930,000
	Engineering/Project Management (8%)				$9,194,000
	Construction Oversight (6%)				$6,896,000
	Contingency (20%)				$22,986,000
				TOTAL (YEARS 2030 - 2030):	$154,006,000
				PRESENT VALUE:	$20,231,000

(See notes on page 7)

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 5 - DREDGING OF SUBMERGED SEDIMENTS WITH UPLAND CONFINED DISPOSAL

Item No.	Remedial Component	Quantity	Units	Unit Cost	Item Cost
C1	**Construction**				
	Mobilization - 1	1	lump sum	$2,175,000	$2,175,000
	General Conditions	1	lump sum	$1,631,000	$1,631,000
	Project Insurance	1	lump sum	$1,087,000	$1,087,000
	Construction Trailers	24	month	$400	$10,000
	Clearing	63,000	linear foot	$21	$1,323,000
	Access road construction/restoration	148,000	square yard	$27	$3,996,000
	CDF Land lease or purchase	776	acre	$8,000	$6,208,000
	CDF clearing & grubbing	776	acre	$7,700	$5,975,000
	CDF bedding	1,243,183	cubic yard	$20	$24,864,000
	CDF exterior dikes	1,182,287	cubic yard	$15	$17,734,000
	CDF interior dikes	1,203,620	cubic yard	$15	$18,054,000
	CDF liner, bot & walls	33,565,938	square foot	$0.50	$16,783,000
	CDF piping	1	lump sum	$3,994,000	$3,994,000
	CDF monitoring wells	27	well	$1,000	$27,000
	WTF site preparation & paving	24,200	square yard	$25	$605,000
	WTF coagulation/flocculation/sedimentation	1	lump sum	$3,281,000	$3,281,000
	WTF multimedia filters	1	lump sum	$2,368,000	$2,368,000
	WTF carbon adsorption	1	lump sum	$1,680,000	$1,680,000
	WTF control building	3,000	square feet	$70	$210,000
	WTF misc pumps, piping & electrical	1	lump sum	$1,629,000	$1,629,000
	SUBTOTAL				$113,634,000
	Engineering/Project Management (8%)				$9,091,000
	Construction Oversight (6%)				$6,818,000
	Contingency (20%)				$22,727,000
				TOTAL (YEARS 2005 - 2005):	$152,270,000
				PRESENT VALUE:	$108,566,000
C1	**Operations**				
	Dredging mobilization - 1	1	lump sum	$7,054,000	$7,054,000
	General Conditions	1	lump sum	$7,299,000	$7,299,000
	Project Insurance	1	lump sum	$4,866,000	$4,866,000
	Construction Trailers	228	month	$400	$91,000
	Dredges, barges, pumps and boats	19	year	$1,482,564	$28,169,000
	Dredge, boat and pump fuel use	19	year	$2,004,701	$38,089,000
	Dredge labor	19	year	$2,421,240	$46,004,000
	Dredge pipelines	19	year	$887,040	$16,854,000
	Silt Curtains, reefing and anchoring	19	year	$246,000	$4,674,000
	Turbidity monitoring stations	1	lump sum	$15,355,000	$15,355,000
	Shoreline protection	1	lump sum	$32,405,000	$32,405,000
	Operate CDF - first pass	5,317	day	$3,086	$16,409,000
	CDF & WTF maintenance	19	year	$4,561,000	$86,659,000
	WTF chemicals	49,789	m gal	$1,500	$74,684,000
	WTF filter media	49,789	m gal	$200	$9,958,000
	WTF activated carbon	49,789	m gal	$1,860	$92,608,000
	Water treatment - first pass	5,317	day	$4,629	$24,612,000
	SUBTOTAL				$505,790,000
	Engineering/Project Management (5%)				$25,290,000
	Construction Oversight (6%)				$30,347,000
	Contingency (20%)				$101,158,000
				TOTAL (YEARS 2005 - 2023):	$662,585,000
				PRESENT VALUE:	$274,972,000

(See notes on page 7)

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 5 - DREDGING OF SUBMERGED SEDIMENTS WITH UPLAND CONFINED DISPOSAL

Item No.	Remedial Component	Quantity	Units	Unit Cost	Item Cost
C2	**Construction**				
	CDF and WTF mobilization - 2	1	lump sum	$176,000	$176,000
	General Conditions	1	lump sum	$132,000	$132,000
	Project Insurance	1	lump sum	$88,000	$88,000
	Construction Trailers	12	month	$400	$5,000
	WTF coagulation/flocculation/sedimentation	1	lump sum	$3,281,000	$3,281,000
	WTF multimedia filters	1	lump sum	$2,368,000	$2,368,000
	WTF carbon adsorption	1	lump sum	$1,680,000	$1,680,000
	WTF misc piping & electrical	1	lump sum	$1,466,000	$1,466,000
	SUBTOTAL				$9,196,000
	Engineering/Project Management (8%)				$736,000
	Construction Oversight (6%)				$552,000
	Contingency (20%)				$1,839,000
				TOTAL (YEARS 2025 - 2025):	$12,323,000
				PRESENT VALUE:	$2,271,000
C2	**Operations**				
	Dredging mobilization - 2	1	lump sum	$2,415,000	$2,415,000
	General Conditions	1	lump sum	$1,811,000	$1,811,000
	Project Insurance	1	lump sum	$1,208,000	$1,208,000
	Construction Trailers	36	month	$400	$14,000
	Dredges, barges, pumps and boats	3	year	$1,741,701	$5,225,000
	Dredge, boat and pump fuel use	3	year	$3,074,621	$9,224,000
	Dredge labor	3	year	$2,421,240	$7,264,000
	Dredge pipelines	3	year	$1,203,840	$3,612,000
	Silt Curtains, reefing and anchoring	3	year	$246,000	$738,000
	Turbidity monitoring stations	1	lump sum	$2,584,000	$2,584,000
	Shoreline protection	1	lump sum	$5,452,000	$5,452,000
	Operate CDF - second pass	596	day	$6,171	$3,678,000
	CDF & WTF maintenance	3	year	$5,001,000	$15,003,000
	WTF chemicals	17,539	m gal	$1,500	$26,309,000
	WTF filter media	17,539	m gal	$200	$3,508,000
	WTF activated carbon	17,539	m gal	$1,860	$32,623,000
	Water treatment - second pass	596	day	$9,257	$5,517,000
	SUBTOTAL				$126,185,000
	Engineering/Project Management (5%)				$6,309,000
	Construction Oversight (6%)				$7,571,000
	Contingency (20%)				$25,237,000
				TOTAL (YEARS 2026 - 2028):	$165,302,000
				PRESENT VALUE:	$26,643,000
C3	**Construction**				
	Mobilization - 3	1	lump sum	$8,796,000	$8,796,000
	General Conditions	1	lump sum	$6,597,000	$6,597,000
	Project Insurance	1	lump sum	$4,398,000	$4,398,000
	Construction Trailers	12	month	$400	$5,000
	Decommission water treat facilities	1	lump sum	$7,427,000	$7,427,000
	CDF top liner	33,565,938	square foot	$0.50	$16,783,000
	CDF cover material	3,729,549	cubic yard	$25	$93,239,000
	CDF 2% graded cap	12,893,138	cubic yard	$25	$322,328,000
	SUBTOTAL				$459,573,000
	Engineering/Project Management (8%)				$36,766,000
	Construction Oversight (6%)				$27,574,000
	Contingency (20%)				$91,915,000
				TOTAL (YEARS 2033 - 2033):	$615,828,000
				PRESENT VALUE:	$66,038,000

(See notes on page 7)

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 5 - DREDGING OF SUBMERGED SEDIMENTS WITH UPLAND CONFINED DISPOSAL

Item No.	Remedial Component	Quantity	Units	Unit Cost	Item Cost
	SUBTOTAL DREDGING CONSTRUCTION				$1,141,295,000
	SUBTOTAL DREDGING OPERATION				$1,413,321,000
	SUBTOTAL DREDGING				$2,554,616,000
	SUBTOTAL PRESENT WORTH DREDGING CONSTRUCTION				$294,716,000
	SUBTOTAL PRESENT WORTH DREDGING OPERATION				$530,612,000
	SUBTOTAL PRESENT WORTH DREDGING				$825,328,000
D1	**Annual Costs**	Years	Annual	Total	Present Worth
	Bathymetric surveys	(2005 - 2028)	$50,000	$1,200,000	$437,000
	Confirmation sampling and analyses	(2005 - 2033)	$832,000	$24,128,000	$7,793,000
	Bank observation	(2017 - 2051)	$32,000	$1,120,000	$140,000
	Bank maintenance	(2017 - 2051)	$424,743	$14,866,000	$1,863,000
	Monitoring - biota	(2006 - 2058)	$137,472	$7,286,000	$1,361,000
	Monitoring - water & sed	(2006 - 2058)	$126,943	$6,728,000	$1,257,000
	KALSIM model updates	(2006 - 2058)	$118,189	$6,264,000	$1,170,000
	CDF & groundwater monitoring - A	(2007 - 2058)	$8,808	$458,000	$81,000
	CDF & groundwater monitoring - B	(2007 - 2058)	$12,808	$666,000	$118,000
	CDF & groundwater monitoring - C	(2007 - 2058)	$21,596	$1,123,000	$199,000
	SUBTOTAL ANNUAL				$1,765,000
	SUBTOTAL ANNUAL ALL YEARS				$63,839,000
	SUBTOTAL ANNUAL PRESENT WORTH ALL YEARS				$14,419,000
				GRAND TOTAL COST:	**$2,618,455,000**
				GRAND TOTAL PRESENT WORTH COST:	**$839,747,000**

NOTES/ASSUMPTIONS

General:

- All costs include material and labor, unless otherwise noted.
- Costs do not include legal fees, permitting, obtaining access, negotiations, or agency oversight.
- Unit costs are in 2000 dollars and are estimated from standard estimating guides (e.g Means Site Work and Landscape Cost Data, vendors, professional judgement and experience from other similar projects).
- Costs based on current site information and project understanding This may change following collection of additional data and/or receipt of Agency input and actual project design
- Cost estimates are generally developed based on the USEPA guidance document "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study", EPA 540-R-00-002 (OSWER 9355.0-75) dated July 2000.
- Present worth is estimated based on a 7 percent (%) beginning-of-year discount rate (adjusted for inflation) in accordance with USEPA policy directive entitled "Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis, OSWER Directive No 9355.3-20 (USEPA, 1993) It is assumed that Year 0 is 2000.
- It is assumed that the construction activities for Alternative 6 would commence in 2005, when all OU and source control activities are complete. Bank stabilization activities at the Trowbridge Impoundment would occur in years 2018 and 2019. Bank stabilization for the Plainwell and Otsego impoundments would occur in 2013 and 2017, respectively.
- Engineering fees, project management and construction management are generally based on percentages shown on Exhibit 5-8 of the USEPA guidance document for feasibility study (OSWER 9355 0-075)
- A 20% contingency allowance is included to provide for unforeseen circumstances or variability in estimated areas, volumes, labor and material costs.
- *Additional Dredge Cost Assumptions and calculations are included on Table 4 1.*

Specific:

- Mobilization/demobilization is a lump sum based on project size
- General conditions refer to contractor overhead, and miscellaneous costs such as health and safety and construction trailer facility. Cost is a lump sum based on project size.
- Labor prices in accordance with Prevailing Rate Schedule, Kalamazoo Co., 1/1/2000 at 40hrs/wk/shift straight time and 14 hrs overtime/wk/shift.
- Access area development includes clearing and preparation of equipment and material staging/handling areas. Restoration includes the removal and disposal of gravel, fill replacement, where necessary, followed by topsoil and vegetation
- Access road construction assumes construction and restoration of a 16-foot wide roadway along both sides of the former impoundments, along one side of the in-between stretches and as needed to access the current impoundments, as further described in Alternatives 3 and 4.
- Bank Stabilization costs as described for Alternatives 3 and 4, including components for Plainwell, Otsego, and Trowbridge impoundments.
- *Dredging by hydraulic cutterhead dredge, assuming 600 cy/day production when dredging in the Kalamazoo River and 2,000 cy/day production when dredging in Lake Allegan* A second overdredge of a 6-inch layer is assumed for all areas
- Cost of 13" Cutterhead Dredge at $2,400,000 amortized at 7.0% for 15-year life results in annual owner cost of $263,507
- Dual layer vinyl coated polyester silt curtain includes reefing and anchoring. It is assumed that 3,800 linear feet will be replaced yearly. Silt curtain based on Elastec quotation, 9/98 escalated to 1/00

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
ALTERNATIVE 5 - DREDGING OF SUBMERGED SEDIMENTS WITH UPLAND CONFINED DISPOSAL

- Five real-time turbidity monitoring stations are used for each dredging segment. Fixed monitoring stations are constructed of 6-in steel piling for each dredging segment, and removed after dredging. It is assumed that turbidity sensors will be replaced every 90,000 cy of dredging
- Sheet piling will be placed along certain stretches to protect onshore facilities from dredging disturbance. It is assumed that this will be required along 10 percent of the shoreline
- Cost of Boat at $350,000 amortized at 7 0% for 10-year life results in annual owner cost of $49,832
- Boat consumes total energy of 35 HP at Engine Fuel Factor (EFF) of 0.042 and fuel price of $1.80/ gal. for fuel costs of $2.65 per hour for 10 active hours per day; while idling 14 hrs per day fuel costs are $0.265 per hr or $3 71 per day, for total fuel costs of $30 per day.
- 6 miles avg. pipeline reach

<u>SEGMENTS A1 & B1</u>

- First-pass dredging of Kalamazoo River segments at. 60 cy/hr, 10 hrs/day, 6 days/wk, 4 wk/mo, 10 mo/yr, 2,400 hrs/yr, or 144,000 cy/yr
- In-situ solids = 77%, dredge solids = 5%, dredge slurry pumping rate = 12.9 cfs during 10-hr/day
- Cost of 13" Cutterhead Dredge at $2,400,000 amortized at 7.0% for 15-year life results in annual owner cost of $263,507.
- 13" Cutterhead Dredge consumes total energy of 2630 HP at EFF of 0.042 and fuel price of $1.80/ gal. for fuel costs of $199 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $19 9 per hr or $279 per day, for total fuel costs of $2,269 per day.
- Three 13-inch booster pumps consume total energy of 311 HP at EFF of 0.042 and fuel price of $1.80/ gal, for fuel costs of $24 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $2.4 per hr or $34 per day, for total fuel costs of $274 per day.

<u>SEGMENTS A2 & B2</u>

- Second-pass dredging of Kalamazoo River segments at: 60 cy/hr, 10 hrs/day; 6 days/wk; 4 wk/mo. 10 mo/yr, 2,400 hrs/yr; or 144,000 cy/yr
- In-situ solids = 77%, dredge solids = 2.5%, dredge slurry pumping rate = 26.2 cfs during 10-hr/day.
- Cost of 18" Cutterhead Dredge at $3,900,000 amortized at 7 0% for 20-year life results in annual owner cost of $368,132.
- 18" Cutterhead Dredge consumes total energy of 4,148 HP at EFF of 0.042 and fuel price of $1.80/ gal. for fuel costs of $314 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $31.4 per hr or $440 per day, for total fuel costs of $3,580 per day.
- Three 18-inch booster pumps consume total energy of 630 HP at EFF of 0.042 and fuel price of $1.80/ gal, for fuel costs of $48 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $4 80 per hr or $67 per day, for total fuel costs of $547 per day.

<u>SEGMENT C1</u>

- First-pass dredging of Lake Allegan at 200 cy/hr; 10 hrs/day, 6 days/wk, 4 wk/mo; 10 mo/yr, 2,400 hrs/yr; or 480,000 cy/yr
- In-situ solids = 77%, dredge solids = 5%, dredge slurry pumping rate = 43 cfs during 10-hr/day, or two dredges, each at 21.5 cfs dredge slurry pumping rate.
- Cost of Two 18" Cutterhead Dredges at $7,800,000 amortized at 7 0% for 20-year life results in annual owner cost of $736,265
- Two 18" Cutterhead Dredges consume total energy of 8,296 HP at EFF of 0.042 and fuel price of $1.80/ gal. for fuel costs of $628 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $62.80 per hr or $879 per day, for total fuel costs of $7,159 per day
- Six 18-inch booster pumps consume total energy of 1,035 HP at EFF of 0 042 and fuel price of $1 80/ gal, for fuel costs of $78 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $7.80 per hr or $109 per day, for total fuel costs of $889 per day.

<u>SEGMENT C2</u>

- Second-pass dredging of Lake Allegan at. 200 cy/hr; 10 hrs/day, 6 days/wk; 4 wk/mo, 10 mo/yr, 2,400 hrs/yr; or 480,000 cy/yr
- In-situ solids = 77%; dredge solids = 2 5%, dredge slurry pumping rate = 87 4 cfs during 10-hr/day, or two dredges, each at 43.7 cfs dredge slurry pumping rate.
- Cost of Two 24" Cutterhead Dredges at $11,600,000 amortized at 7.0% for 25-year life results in annual owner cost of $995,402
- Two 24" Cutterhead Dredges consume total energy of 12,410 HP at EFF of 0.042 and fuel price of $1.80/ gal. for fuel costs of $938 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $93.80 per hr or $1,313 per day, for total fuel costs of $10,693 per day
- Six 24-inch booster pumps consume total energy of 2,099 HP at EFF of 0.042 and fuel price of $1.80/ gal, for fuel costs of $159 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $15 90 per hr or $223 per day, for total fuel costs of $1,813 per day.
- CDF area requirement is based on achieving long-term solids content of 47% w/w in facilities with 20-ft ultimate height. Three facilities are anticipated, with total containment volume of 25 3 million cy. Side slopes of 1 3 add additional area requirements, in addition to adjacent facilities for water treatment.
- CDF sizing is in accordance with Engineer Manual 1110-2-5027, Engineering and Design, Confined Disposal of Dredged Material, USACE (30 Sep 1987)
- CDFs are assumed to contain a sand bedding of 1-ft, underdrains and polyethylene lining, prior to commencement of operation. Sizing of the CDFs assume 8 internal dikes will be constructed to facilitate operation and consolidation of sediment
- Water treatment for overflow of dredge water from the CDF consists of flocculation, sedimentation, dual-media filtration and activated carbon adsorption. Discharge is to the Kalamazoo River or Lake Allegan. Treatment facilities are located adjacent to each of the three CDFs Unit costs are based on experience at the Fox River SMU 56/57, with elimination of neutralization chemical costs. Flocculation and sedimentation assume 60 min. detention, filtration facilities are assumed to be loaded at 2.0 gpd/sf, and carbon contactors assume empty bed contact time of 20 min
- Control building of 1,500 square ft to be constructed for each WTF
- Closure of completed CDFs, after five years of final consolidation, would consist of a polyethylene membrane, one foot of soil cover and a 2%-sloped soil cap for runoff control
- Bathymetric surveys are performed annually during dredging.
- Confirmation Sampling includes analyses and QA/QC for in-situ sediments, waters and residuals for dredging and water treatment operations
- Construction oversight includes project management and daily reports
- Engineering fees are based on 8% of the construction subtotal cost or 5% of operational costs during field execution.
- Contingency is based upon 20% of the construction subtotal cost
- Present worth dredging and disposal cost assumes costs are spread evenly over the duration of each program segment, at a 7% discount rate.
- Present worth cost includes institutional controls and monitoring. Samples for Advisory Monitoring of Biota are taken at year 1, then every 5 years until 30 years after completion of dredging Samples for Trend Monitoring of Biota are taken at year 1, then every 3 years until 30 years after completion of dredging. Water and sediment samples are taken at year 1, then every 5 years until 30 years after completion of dredging KALSIM model updates are performed at year 1, then every 5 years until 30 years after completion of dredging
- Annual costs for maintenance of restored impoundments as developed for Alternative 3.
- CDF monitoring consists of sampling and analyses of perimeter monitoring wells for 52 years
- Total present worth cost is the sum of costs for dredging, disposal, water treatment, institutional controls, and monitoring.

TABLE 4.1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
DREDGE COST ASSUMPTIONS
ALTERNATIVE 5 - DREDGING OF SUBMERGED SEDIMENTS WITH UPLAND CONFINED DISPOSAL

SEGMENTS A1 & B1

- First-pass dredging of Kalamazoo River segments at: 60 cy/hr; 10 hrs/day, 6 days/wk. 4 wk/mo; 10 mo/yr. 2,400 hrs/yr, or 144,000 cy/yr
- In-situ solids = 77%. dredge solids = 5%; dredge slurry pumping rate = 12 9 cfs during 10-hr/day
- Dredge sizing to maintain pipeline velocity of 15 fps is 12.6 inches; therefore select 13-inch dredge

Equipment and Operating Costs

	Item	No.	Units	Unit cost	(Annual) Tot cost
1	13" Cutterhead Dredge	240	days	$1,098	$263,507
2	Boat	240	days	$208	$49,832
2	Boat	240	days	$208	$49,832
3,4	Fuel	240	days	$2,331	$559,320
5	Dredge operator (3 shifts/day)	40	weeks	$5,905	$236,201
6	Engineer (3 shifts/day)	40	weeks	$5,779	$231,142
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
2	Barge for debris	240	days	$59	$14,238
2	Barge for debris	240	days	$59	$14,238
2	Boat, debris crew	240	days	$208	$49,832
4	Fuel	240	days	$31	$7,440
2	Boat, debris crew	240	days	$208	$49,832
4	Fuel	240	days	$31	$7,440
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
8	Silt Curtains, reefing and anchoring	3,800	LF/yr	$32	$123,000
2	Boat	240	days	$208	$49,832
4	Fuel	240	days	$30	$7,200
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
9	3 Booster pumps and barges	240	days	$457	$109,751
10	Booster pump fuel	240	days	$274	$65,760
11	13" Pipeline	31,680	LF/yr	$22	$696,960
2	Boat	240	days	$208	$49,832
4	Fuel	240	days	$30	$7,250
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
				Total:	$3,478,681
				Total $/cy dredged:	$24.16

Notes

1. Cost of 13" Cutterhead Dredge at $2,400,000 amortized at 7.0% for 15-year life results in annual owner cost of $26,3507.
2. Cost of Boat at $350,000 amortized at 7 0% for 10-year life results in annual owner cost of $49,832
3. 13" Cutterhead Dredge consumes total energy of 2,630 HP at Engine Fuel Factor (EFF) of 0.042 and fuel price of $1.80/ gal, for fuel costs of $199 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $19 9 per hr or $279 per day, for total fuel costs of $2,269 per day
4. Boat consumes total energy of 35 HP at EFF of 0 042 and fuel price of $1.80/ gal, for fuel costs of $2 65 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $0 265 per hr or $3.71 per day, for total fuel costs of $30 per day
5. Crane engineer, Prevailing Rate Schedule, Kalamazoo Co , 1/1/2000 at 33 35$/hr, straight for 40hrs/wk/shift and 45.31$/hr, ot for 14hrs ot/wk/shift, resulting in 1,968 34$/wk/shift or 5,905.02$/wk for 3 shifts.
6. Class I engineer, Prevailing Rate Schedule Kalamazoo Co , 1/1/2000 at 32 66$/hr, straight for 40hrs/wk/shift and 44.27$/hr, ot for 14hrs ot/wk/shift, resulting in 1,926.18$/wk/shift or 5,778.54$/wk for 3 shifts.
7. Laborer Class B, Prevailing Rate Schedule, Kalamazoo Co , 1/1/2000 at 22 52$/hr, straight for 40hrs/wk/shift and 32.43$/hr, ot for 14hrs ot/wk/shift, resulting in 1,354.82$/wk/shift or 4 064 46$/wk for 3 shifts Debris crew at 10 hrs/day or 40 hrs straight time and 20 hrs ot per week
8. Elastec quotation, 9/98 escalated to 1/00, replace yearly
9. Cost of 3 Booster pumps and barges at $450,000 amortized at 7 0% for 5-year life results in annual owner cost of $109,751.
10. Three 13-inch booster pumps consume total energy of 311 HP at EFF of 0.042 and fuel price of $1 80/ gal, for fuel costs of $24 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $2.4 per hr or $34 per day, for total fuel costs of $274 per day.
11. 6 miles avg. pipeline reach

TABLE 4.1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
DREDGE COST ASSUMPTIONS
ALTERNATIVE 5 - DREDGING OF SUBMERGED SEDIMENTS WITH UPLAND CONFINED DISPOSAL

SEGMENTS A2 & B2

- Second-pass dredging of Kalamazoo River segments at. 60 cy/hr. 10 hrs/day. 6 days/wk. 4 wk/mo. 10 mo/yr. 2,400 hrs/yr: or 144,000 cy/yr
- In-situ solids = 77%; dredge solids = 2 5%. dredge slurry pumping rate = 26 2 cfs during 10-hr/day
- Dredge sizing to maintain pipeline velocity of 15 fps is 17 9 inches; therefore select 18-inch dredge

Equipment and Operating Costs

	Item	No.	Units	Unit cost	(Annual) Tot cost
1	18" Cutterhead Dredge	240	days	$1.534	$368.132
2	Boat	240	days	$208	$49,832
2	Boat	240	days	$208	$49,832
3 4	Fuel	240	days	$3.642	$873,960
5	Dredge operator (3 shifts/day)	40	weeks	$5,905	$236,201
6	Engineer (3 shifts/day)	40	weeks	$5,779	$231,142
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
2	Barge for debris	240	days	$59	$14,238
2	Barge for debris	240	days	$59	$14,238
2	Boat, debris crew	240	days	$208	$49,832
4	Fuel	240	days	$31	$7,440
2	Boat, debris crew	240	days	$208	$49,832
4	Fuel	240	days	$31	$7,440
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
8	Silt Curtains, reefing and anchoring	3,800	LF/yr	$32	$123,000
2	Boat	240	days	$208	$49,832
4	Fuel	240	days	$30	$7,200
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
9	3 Booster pumps and barges	240	days	$457	$109,751
10	Booster pump fuel	240	days	$547	$131,280
11	18" Pipeline	31,680	LF/yr	$24	$760,320
2	Boat	240	days	$208	$49,832
4	Fuel	240	days	$30	$7,250
7	Laborer (3 shifts/day)	40	weeks	$4.064	$162,578
				Total:	$4,026,826
				Total $/cy dredged:	$27 96

Notes

1 Cost of 18" Cutterhead Dredge at $3,900,000 amortized at 7.0% for 20-year life results in annual owner cost of $368,132.

2 Cost of Boat at $350,000 amortized at 7.0% for 10-year life results in annual owner cost of $49,832.

3 18" Cutterhead Dredge consumes total energy of 4148 HP at Engine Fuel Factor (EFF) of 0.042 and fuel price of $1.80/ gal, for fuel costs of $314 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $31.4 per hr or $440 per day, for total fuel costs of $3,580 per day.

9 Cost of 3 Booster pumps and barges at $450,000 amortized at 7.0% for 5-year life results in annual owner cost of $109,751.

10 Three 18-inch booster pumps consume total energy of 630 HP at EFF of 0.042 and fuel price of $1.80/ gal, for fuel costs of $48 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $4.8 per hr or $67 per day, for total fuel costs of $547 per day.

11 6 miles avg pipeline reach

TABLE 4.1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
DREDGE COST ASSUMPTIONS
ALTERNATIVE 5 - DREDGING OF SUBMERGED SEDIMENTS WITH UPLAND CONFINED DISPOSAL

SEGMENT C1

- First-pass dredging of Lake Allegan at 200 cy/hr. 10 hrs/day. 6 days/wk. 4 wk/mo. 10 mo/yr. 2.400 hrs/yr. or 480,000 cy/yr
- In-situ solids = 77%. dredge solids = 5%. dredge slurry pumping rate = 43 cfs during 10-hr/day. or two dredges. each at 21 5 cfs dredge slurry pumping rate.
- Dredge sizing to maintain pipeline velocity of 15 fps is 16.2 inches. therefore select two 20-inch dredges

Equipment and Operating Costs

	Item	No.	Units	Unit cost	(Annual) Tot cost
1	Two 18" Cutterhead Dredges	240	days	$3,068	$736,265
2	Boat	240	days	$208	$49,832
2	Boat	240	days	$208	$49,832
2	Boat	240	days	$208	$49,832
2	Boat	240	days	$208	$49,832
3,4	Fuel	240	days	$7,282	$1,747,560
5	Dredge operator (3 shifts/day)	40	weeks	$5,905	$236,201
5	Dredge operator (3 shifts/day)	40	weeks	$5,905	$236,201
6	Engineer (3 shifts/day)	40	weeks	$5,779	$231,142
6	Engineer (3 shifts/day)	40	weeks	$5,779	$231,142
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
2	Barge for debris	240	days	$59	$14,238
2	Barge for debris	240	days	$59	$14,238
2	Boat, debris crew	240	days	$208	$49,832
4	Fuel	240	days	$31	$7,440
2	Boat, debris crew	240	days	$208	$49,832
4	Fuel	240	days	$31	$7,440
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
8	Silt Curtains, reefing and anchoring	7,600	LF/yr	$32	$246,000
2	Boat	240	days	$208	$49,832
4	Fuel	240	days	$30	$7,200
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
2	Boat	240	days	$208	$49,832
4	Fuel	240	days	$30	$7,200
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
9	6 Booster pumps and barges	240	days	$915	$219,502
10	Booster pump fuel	240	days	$889	$213,360
11	20" Pipeline	31,680	LF/yr	$28	$887,040
2	Boat	240	days	$208	$49,832
4	Fuel	240	days	$30	$7,250
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
2	Boat	240	days	$208	$49,832
4	Fuel	240	days	$30	$7,250
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
				Total:	$7,041,545
				Total $/cy dredged:	$14 67

Notes

1 Cost of Two 18" Cutterhead Dredges at $7 800,000 amortized at 7.0% for 20-year life results in annual owner cost of $736,265.

2 Cost of Boat at $350,000 amortized at 7 0% for 10-year life results in annual owner cost of $49,832.

3 Two 18" Cutterhead Dredges consume total energy of 8296 HP at Engine Fuel Factor (EFF) of 0 042 and fuel price of $1.80/ gal, for fuel costs of $628 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $62.8 per hr or $879 per day, for total fuel costs of $7,159 per day

4 Boat consumes total energy of 35 HP at EFF of 0.042 and fuel price of $1 80/ gal. for fuel costs of $2.65 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $0 265 per hr or $3.71 per day, for total fuel costs of $30 per day

5 Crane engineer, Prevailing Rate Schedule, Kalamazoo Co., 1/1/2000 at 33.35$/hr straight for 40hrs/wk/shift and 45.31$/hr, ot for 14hrs ot/wk/shift, resulting in 1,968.34$/wk/shift or 5,905 02$/wk for 3 shifts.

6 Class I engineer, Prevailing Rate Schedule, Kalamazoo Co., 1/1/2000 at 32 66$/hr. straight for 40hrs/wk/shift and 44.27$/hr. ot for 14hrs ot/wk/shift, resulting in 1,926 18$/wk/shift or 5,778.54$/wk for 3 shifts.

7 Laborer Class B, Prevailing Rate Schedule Kalamazoo Co., 1/1/2000 at 22.52$/hr straight for 40hrs/wk/shift and 32.43$/hr. ot for 14hrs ot/wk/shift, resulting in 1,354 82$/wk/shift or 4 064 46$/wk for 3 shifts Debris crew at 5 hrs/day or 30 hrs straight time and 0 hrs ot per week

8 Elastec quotation, 9/98 escalated to 1/00, replace yearly.

9 *Cost of 6 Booster pumps and barges at $900 000 amortized at 7.0% for 5-year life results in annual owner cost of $219,502*

10 Six 18-inch booster pumps consume total energy of 1035 HP at EFF of 0 042 and fuel price of $1 80/ gal. for fuel costs of $78 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $7.8 per hr or $109 per day, for total fuel costs of $889 per day.

11 6 miles avg pipeline reach

TABLE 4.1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
DREDGE COST ASSUMPTIONS
ALTERNATIVE 5 - DREDGING OF SUBMERGED SEDIMENTS WITH UPLAND CONFINED DISPOSAL

SEGMENT C2

- Second-pass dredging of Lake Allegan at. 200 cy/hr, 10 hrs/day, 6 days/wk; 4 wk/mo, 10 mo/yr. 2,400 hrs/yr. or 480,000 cy/yr
- In-situ solids = 77%, dredge solids = 2 5%, dredge slurry pumping rate = 87.4 cfs during 10-hr/day, or two dredges, each at 43 7 cfs dredge slurry pumping rate
- Dredge sizing to maintain pipeline velocity of 15 fps is 23 1 inches, therefore select two 30-inch dredges.

Equipment and Operating Costs

	Item	No.	Units	Unit cost	(Annual) Tot cost
1	Two 24" Cutterhead Dredges	240	days	$4,148	$995,402
2	Boat	240	days	$208	$49,832
2	Boat	240	days	$208	$49,832
2	Boat	240	days	$208	$49,832
2	Boat	240	days	$208	$49,832
3,4	Fuel	240	days	$10,816	$2,595,720
5	Dredge operator (3 shifts/day)	40	weeks	$5,905	$236,201
5	Dredge operator (3 shifts/day)	40	weeks	$5,905	$236,201
6	Engineer (3 shifts/day)	40	weeks	$5,779	$231,142
6	Engineer (3 shifts/day)	40	weeks	$5,779	$231,142
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
2	Barge for debris	240	days	$59	$14,238
2	Barge for debris	240	days	$59	$14,238
2	Boat, debris crew	240	days	$208	$49,832
4	Fuel	240	days	$31	$7,440
2	Boat, debris crew	240	days	$208	$49,832
4	Fuel	240	days	$31	$7,440
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
8	Silt Curtains, reefing and anchoring	7,600	LF/yr	$32	$246,000
2	Boat	240	days	$208	$49,832
4	Fuel	240	days	$30	$7,200
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
2	Boat	240	days	$208	$49,832
4	Fuel	240	days	$30	$7,200
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
9	6 Booster pumps and barges	240	days	$915	$219,502
10	Booster pump fuel	240	days	$1,813	$435,120
11	30" Pipeline	31,680	LF/yr	$38	$1,203,840
2	Boat	240	days	$208	$49,832
4	Fuel	240	days	$30	$7,250
7	Laborer (3 shifts/day)	40	weeks	$4 064	$162,578
2	Boat	240	days	$208	$49,832
4	Fuel	240	days	$30	$7,250
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
				Total:	$8,687,402
				Total $/cy dredged:	$18.10

Notes

1 Cost of Two 24" Cutterhead Dredges at $11,600,000 amortized at 7 0% for 25-year life results in annual owner cost of $995,402.

2 Cost of Boat at $350,000 amortized at 7 0% for 10-year life results in annual owner cost of $49,832

3 Two 24" Cutterhead Dredges consume total energy of 12,410 HP at Engine Fuel Factor (EFF) of 0 042 and fuel price of $1 80/ gal. for fuel costs of $938 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $93.80 per hr or $1,313 per day, for total fuel costs of $10,693 per day

4 Boat consumes total energy of 35 HP at EFF of 0.042 and fuel price of $1 80/ gal, for fuel costs of $2.65 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $0.265 per hr or $3 71 per day, for total fuel costs of $30 per day.

5 Crane engineer, Prevailing Rate Schedule, Kalamazoo Co., 1/1/2000 at 33.35$/hr, straight for 40hrs/wk/shift and 45.31$/hr, ot for 14hrs ot/wk/shift, resulting in 1,968.34$/wk/shift or 5,905 02$/wk for 3 shifts

6 Class I engineer, Prevailing Rate Schedule, Kalamazoo Co , 1/1/2000 at 32.66$/hr, straight for 40hrs/wk/shift and 44 27$/hr, ot for 14hrs ot/wk/shift, resulting in 1,926.18$/wk/shift or 5,778 54$/wk for 3 shifts

7 Laborer Class B, Prevailing Rate Schedule, Kalamazoo Co , 1/1/2000 at 22.52$/hr, straight for 40hrs/wk/shift and 32.43$/hr, ot for 14hrs ot/wk/shift, resulting in 1,354.82$/wk/shift or 4,064.46$/wk for 3 shifts Debris crew at 5 hrs/day or 30 hrs straight time and 0 hrs ot per week

8 Elastec quotation, 9/98 escalated to 1/00, replace yearly.

9 Cost of 6 Booster pumps and barges at $900,000 amortized at 7 0% for 5-year life results in annual owner cost of $219,502

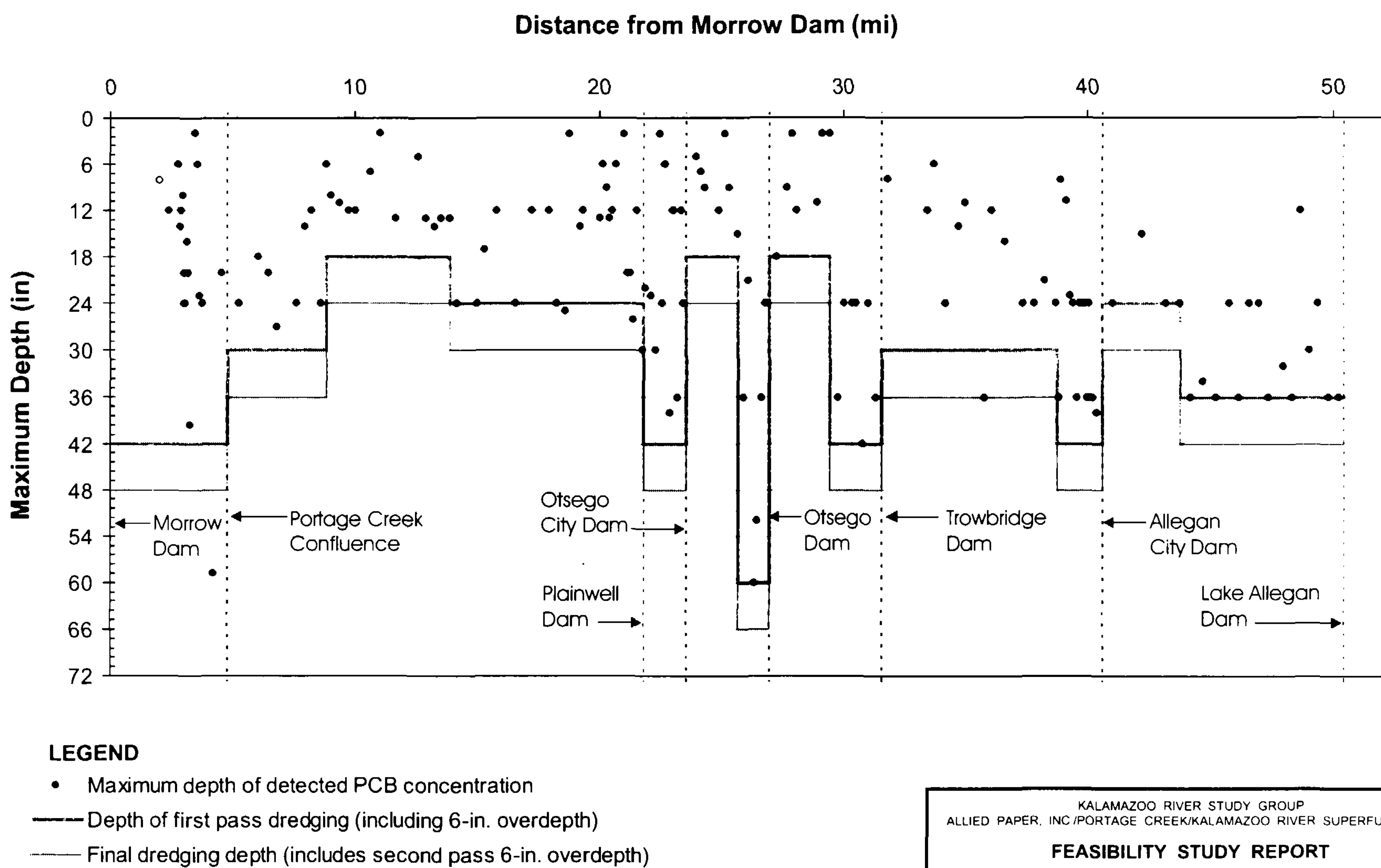
10 Six 24-inch booster pumps consume total energy of 2,099 HP at EFF of 0 042 and fuel price of $1.80/ gal. for fuel costs of $159 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $15.9 per hr or $223 per day, for total fuel costs of $1,813 per day.

11 6 miles avg. pipeline reach

12 Dredge Plant Ownership and Operating Rates, See USACE, 1999 - Section 4.

Figures

BLASLAND, BOUCK & LEE, INC.
engineers & scientists



DRAFT
FOR STATE AND FEDERAL REVIEW

KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT

MAXIMUM DEPTH OF DETECTED PCB CONCENTRATIONS AND ASSOCIATED DREDGING DEPTHS

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 1

9/00 SYR-54-YCC
64524600/64524G01 CDR

LEGEND

FLOW DIRECTION

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE BOUNDARY OF FORMER IMPOUNDMENT

0.0 APPROXIMATE RIVER MILES ALONG THE MAIN CHANNEL

TENTATIVE LOCATION OF ACCESS/SEDIMENT HANDLING AREA

APPROXIMATE LOCATION OF PROPOSED ACCESS ROAD AND STABILIZED BANKS

INDICATES LIMITED ACCESS, OR WHERE ACCESS WOULD BE DIFFICULT FOR WATER BASED CONSTRUCTION WORKS

NOTES:

1. PLANIMETRIC MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEMS.
2. AERIAL IMAGE DERIVED FROM ORTHOPHOTOGRAPHIC DATA BY AIR LAND SURVEYS, INC., FLOWN 4/24/99.

0 2400' 4800'

SCALE

DRAFT

FOR STATE AND FEDERAL REVIEW

KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

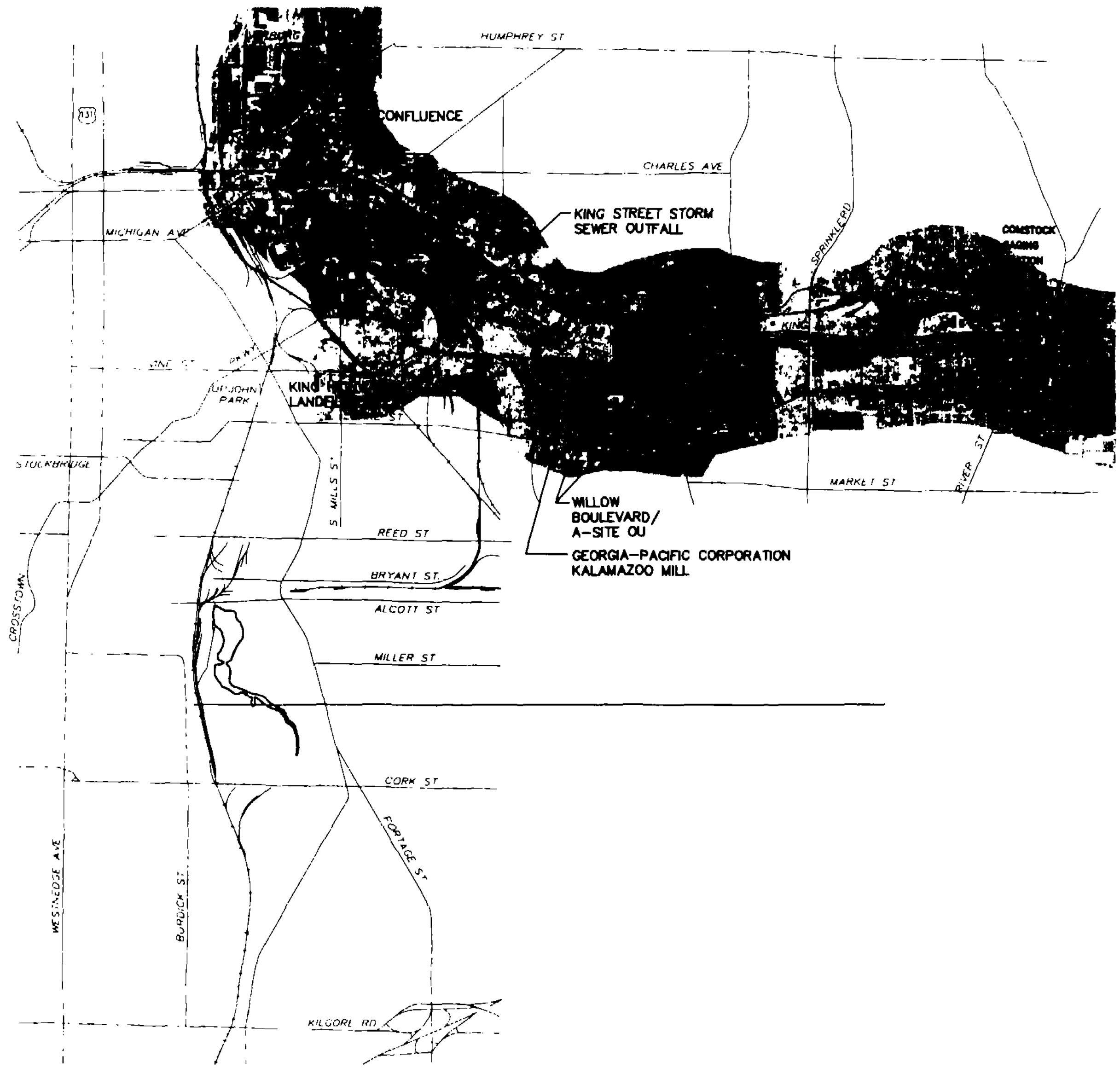
FEASIBILITY STUDY REPORT

MORROW LAKE

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 2

X: 64824R03.TIF
L: ON=*, OFF=*REF*
P: 030-37.PCP
10/28/00 SYR-54-RLP DCC KMD
64824800\OVERVIEW\64824G30.DWG



LEGEND

FLOW DIRECTION

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE BOUNDARY OF FORMER IMPOUNDMENT

1.0 APPROXIMATE RIVER MILES ALONG THE MAIN CHANNEL

TENTATIVE LOCATION OF ACCESS/SEDIMENT HANDLING AREA

APPROXIMATE LOCATION OF PROPOSED ACCESS ROAD AND STABILIZED BANKS

INDICATES LIMITED ACCESS, OR WHERE ACCESS WOULD BE DIFFICULT FOR WATER BASED CONSTRUCTION WORKS

NOTES:

1. PLANIMETRIC MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEMS.
2. AERIAL IMAGE DERIVED FROM ORTHOPHOTOGRAPHIC DATA BY AIR LAND SURVEYS, INC., FLOWN 4/24/99.

0 2400' 4800'

SCALE

DRAFT

FOR STATE AND FEDERAL REVIEW

KALAMAZOO RIVER STUDY GROUP

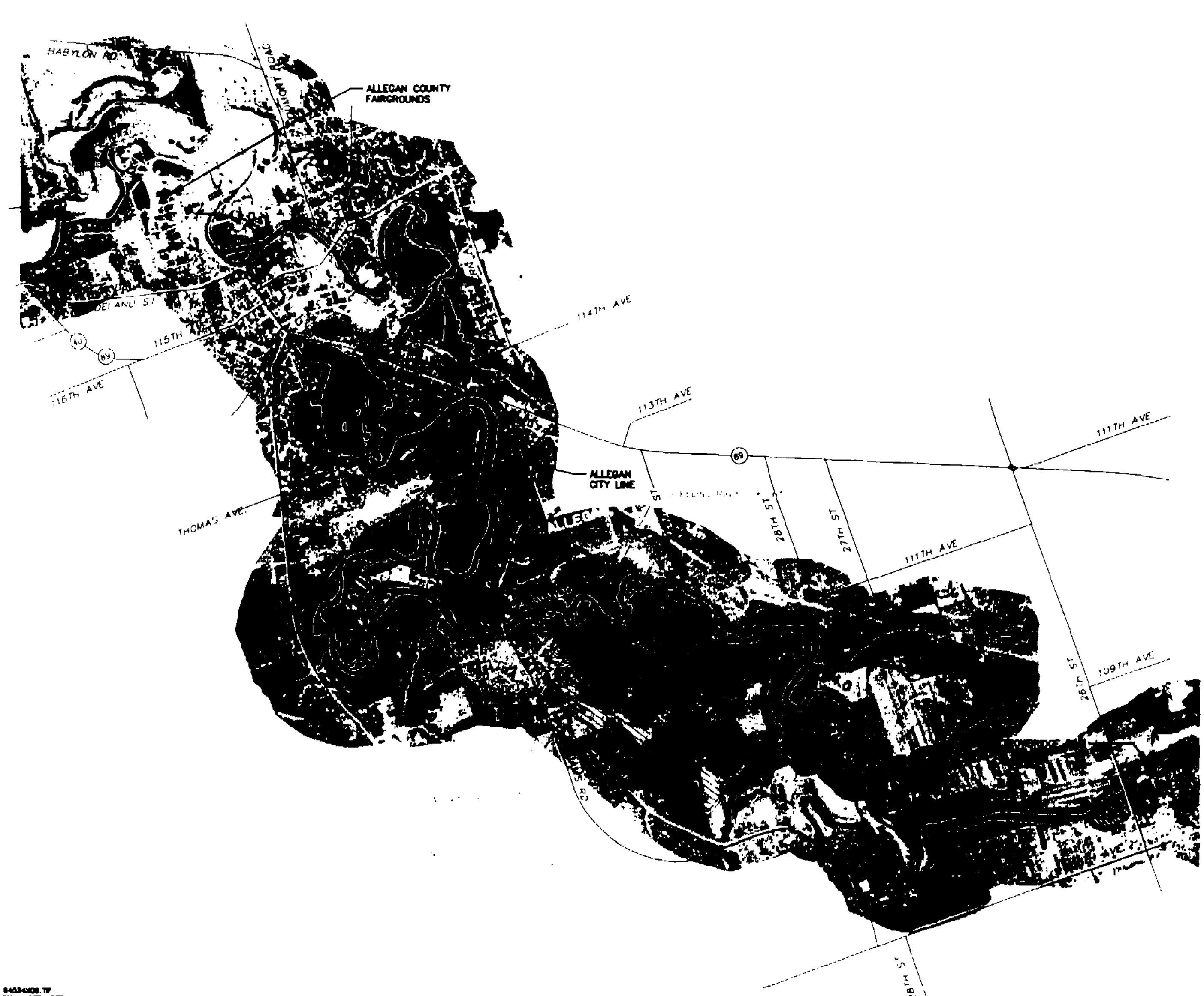
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT

PORTAGE CREEK/KALAMAZOO RIVER CONFLUENCE

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 3



LEGEND

FLOW DIRECTION

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE BOUNDARY OF FORMER IMPOUNDMENT

32.0 APPROXIMATE RIVER MILES ALONG THE MAIN CHANNEL

TENTATIVE LOCATION OF ACCESS/SEDIMENT HANDLING AREA

APPROXIMATE LOCATION OF PROPOSED ACCESS ROAD AND STABILIZED BANKS

INDICATES LIMITED ACCESS, OR WHERE ACCESS WOULD BE DIFFICULT FOR WATER BASED CONSTRUCTION WORKS

NOTES:

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0 2400' 4800'

SCALE

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KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

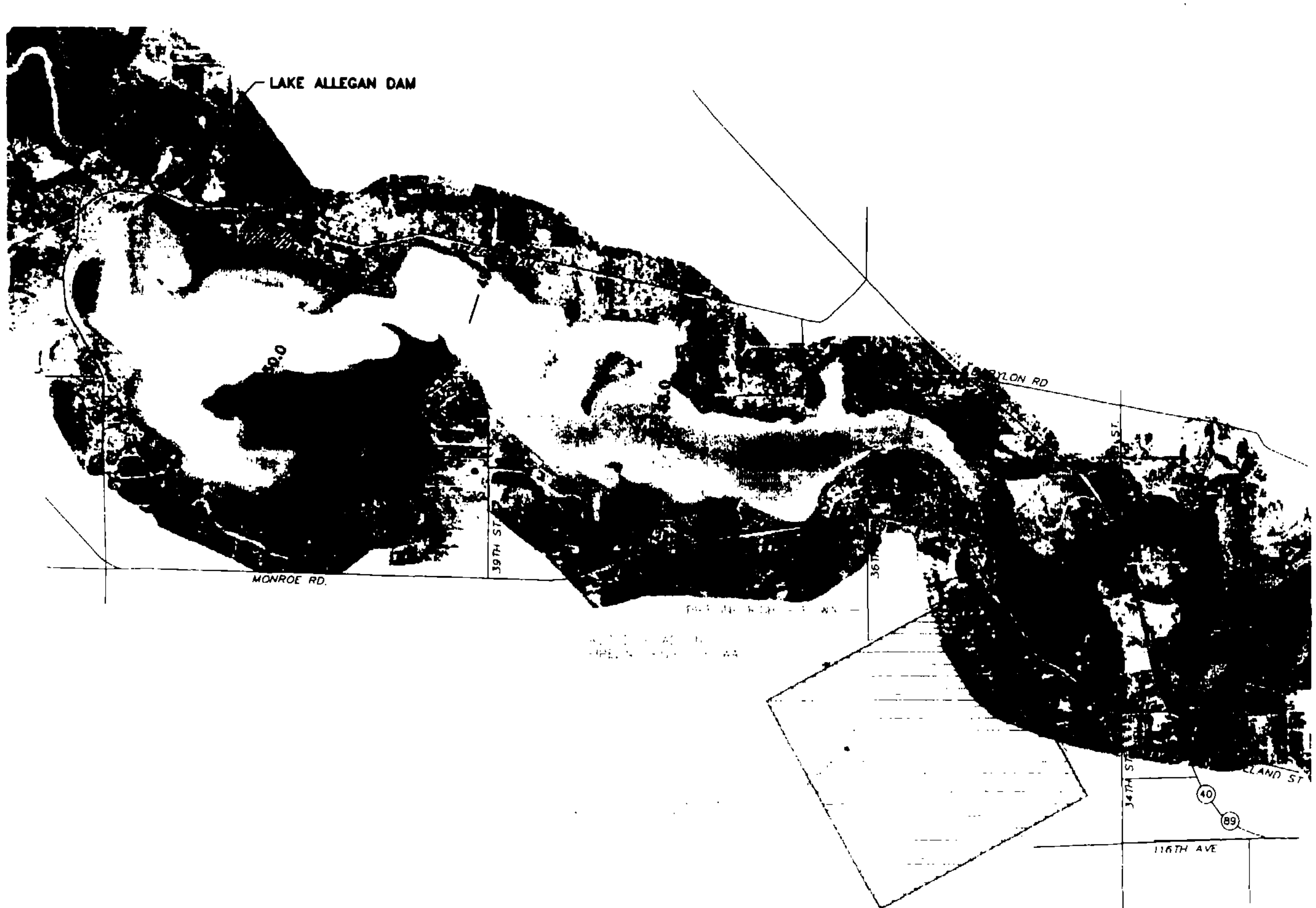
FEASIBILITY STUDY REPORT

KALAMAZOO RIVER FROM TROWBRIDGE DAM TO LAKE ALLEGAN

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 8

X: 64624X08.TIF
L: ON=*, OFF=*REF*
P: G30-37.PCP
10/26/00 SYR-54-RLP GCC KMD
64624600\OVERVIEW\64624G38.DWG



LEGEND

FLOW DIRECTION

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE BOUNDARY OF FORMER IMPOUNDMENT

45.0 APPROXIMATE RIVER MILES ALONG THE MAIN CHANNEL

TENTATIVE LOCATION OF ACCESS/SEDIMENT HANDLING AREA

APPROXIMATE LOCATION OF PROPOSED ACCESS ROAD AND STABILIZED BANKS

INDICATES LIMITED ACCESS, OR WHERE ACCESS WOULD BE DIFFICULT FOR WATER BASED CONSTRUCTION WORKS

NOTES:

1. PLANIMETRIC MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEMS.
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0 2400' 4800'

SCALE

DRAFT

FOR STATE AND FEDERAL REVIEW

KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT

LAKE ALLEGAN

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 9

Appendix F

BLASLAND, BOUCK & LEE, INC.
engineers & scientists

Evaluation of Dam Removal

Appendix F – Evaluation of Dam Removal

Although removal of any of the existing dam sill structures is not a necessary component of any remedial alternative, the Michigan Department of Environmental Quality (MDEQ) has requested consideration in the Feasibility Study (FS) of an approach that would entail removing the Michigan Department of Natural Resources (MDNR)-owned sill structures at Plainwell, Otsego and Trowbridge. In response to this request, the steps that would be required to address the polychlorinated biphenyl (PCB)-containing sediments in the former impoundments, a necessary pre-cursor to the removal of the sill structures followed by the bank stabilization, soil covering, and dam sill removal components of such an alternative are presented in this appendix.

Conceptual Plan – Dredging of Submerged Sediments from the Former Impoundments, Exposed Sediment Soil Cover, Bank Stabilization and Removal of Dam Sills at the Former Impoundments with Upland Confined Disposal at Exposed Sediment Locations, Institutional Controls, and Monitoring

Description

This conceptual plan would include the removal of PCB-containing submerged sediment from the MDNR-owned former impoundment areas (Plainwell, Otsego and Trowbridge) using a series of hydraulic dredges and pumping of the dredged material to three confined disposal facilities (CDFs) located adjacent to the Kalamazoo River (one CDF in each impoundment) on top of locations where exposed sediments already contain PCB. Following construction of the CDFs, a soil cover (1 foot of sand/gravel) would be placed on all the remaining PCB-containing exposed sediments in the former impoundment areas. The conceptual plan also includes removal of what remains of lower portions of the former dams, or sills, that once impounded water in these areas. The opening of these dams caused a rapid redistribution of sediment within the river and exposed significant areas of sediment above the water line that have continued to erode back into the river over the past three decades.

Stabilization of the former impoundment banks, as described in Alternative 3 in the FS, would be implemented after dredging behind the dam sills to ensure that PCB-containing sediments from the bank areas would not continue to erode into the river. Bank stabilization activities would be implemented using an upstream to downstream approach. The institutional controls and monitoring, as discussed in Alternative 3, would also be performed as part of this conceptual plan.

As discussed in Section 4.8 of the FS, the amount of sediment that would be dredged from the Kalamazoo River is a function of the target dredging depth identified for each reach. The initial target dredging depths were estimated using the maximum depth at which PCB has been detected in sediment within each reach, plus an additional 6-inch overdepth layer. Using this approach, the initial volume or quantity of sediment that would be removed from the three former impoundments during "first-pass" dredging is approximately 1,433,000 cubic yards (cy). The gross inefficiencies associated with dredging equipment would require the removal of additional sediment below the initial target depths. The final dredging depth is thus based on the initial target depth, plus the removal of a second 6-inch overdepth layer during a final "clean up" dredging pass. The thickness of the overdepth layer (6 inches) was determined based on the smallest layer of sediment that can reasonably be removed using a small hydraulic dredge operating at close to peak efficiencies. Allowing for this overdepth dredging, which is necessary to even attempt to achieve low PCB residual concentrations, the total estimated volume of sediment to be dredged from the former impoundment areas is approximately 1,630,000 cy. The dredging depth information is summarized below on a reach-specific basis, including the anticipated depth of dredging and the resulting sediment volumes for both the first- and second-pass dredging cuts.

River Reach	Dredged Depth (in)	First-Pass Dredged Volume (cy)	Second-Pass 6-in Overdepth Volume (cy)	Total Dredged Volume (cy)
Main Street, Plainwell to Plainwell Dam	30	232,000	39,000	271,000
Otsego City Dam to Otsego Dam	18-60	495,000	64,000	560,000
Otsego Dam to Trowbridge Dam	18-42	705,000	97,000	802,000
Total (rounded)		1,433,000	200,000	1,633,000

At a production rate of 600 cy/day, and an assumption of 240 working days per calendar year, the maximum annual removal rate is 144,000 cy per year. With a total removal volume of over 1.6 million cy, applying this production rate results in a total dredging time of 11.5 years. Simultaneously dredging the three portions during the first pass could reduce the project time to five years (1.6 years for Plainwell, 3.4 years for Otsego, and 4.9 years for Trowbridge). Second-pass dredging of the Plainwell (0.3 years) and Otsego (0.5 years) portions could also be completed during this period, while second-pass dredging of the Trowbridge component (0.7 years) could be completed during the fifth year. The second-pass dredging would be implemented within each segment using an upstream to downstream approach to minimize the downstream impacts of redistribution of PCB-containing sediment that will result from dredging. Conducting the dredging and bank stabilization activities in this sequence would limit the amount of PCB-containing exposed former sediment that would enter the aquatic environment through ongoing riverbank erosion. It would also allow for the removal of PCB-containing sediment as well as any submerged erodible sediment lying below the PCB-containing sediment prior to removal of the dam sills, which would undoubtedly cause those sediments to be redistributed downstream if they were not removed first.

The dredging component would include clearing and grubbing of debris in the channel areas followed by the removal of approximately 1.6 million cy of submerged sediment with a series of hydraulic cutterhead dredges. The dredged sediment would be transported to the CDFs through pipelines that would be up to five miles in length, requiring several booster pumps to prevent the pipeline from becoming blocked. The water generated during dredging would require treatment prior to discharge back to the river. The dredging, disposal, and water treatment aspects are presented in the description of Alternative 5 (Section 4.8 of the FS).

Dredging is a technology typically used to remove large quantities of sediments from shipping lanes in waterways. The ability or technical feasibility of dredging to achieve environmental restoration objectives is highly questionable based on the results of the limited number of sediment remediation projects conducted to date. Appendix D to the FS Report presents an overview of experiences and problems encountered at other sites when applying dredging technologies to achieve target levels of risk reduction and numerical sediment cleanup goals. Dredges have been inconsistent in their ability to achieve remedial objectives, and often require two, or more, dredging passes in an attempt to do so. If the targeted dredging depths are unable to achieve cleanup criteria, additional remedial action may be necessary, consisting of additional dredging passes. This could exacerbate bank stability problems as the toes of the stream banks become lowered further.

The three CDFs and associated water treatment facilities would occupy a total area of 136 acres, ranging in size from 17 to 60 acres, as shown on Figures 1 through 3. The CDFs would be constructed with 20-foot high lined earthen berms to allow sedimentation and consolidation of sediments from the dredged material slurry. The final consolidation depth would be 16 feet at the time of closure. CDFs would be closed by placing a polyethylene liner and cap with 1 foot of sand and 2 feet of soil cover, plus a 2% graded soil cap for runoff control, as described for Alternative 5.

Overflow water from the CDFs would be treated prior to discharge back to the Kalamazoo River. The unit process operations used for treatment of the water include flocculation, sedimentation, filtration, and two-stage activated carbon adsorption. Water treatment facilities would be constructed adjacent to each of the three CDFs. The three facilities would each be designed to treat 3 million gallons per day (MGD) during first-pass dredging, with upgrading to treat 6 MGD during second-pass dredging. Treatment plant operations would also include monitoring the discharge effluent to ensure compliance with applicable standards.

The exposed sediments in the former impoundments cover approximately 510 acres (59 acres in the former Plainwell Impoundment, 77 acres in the former Otsego Impoundment, and 374 acres in the former Trowbridge Impoundment). CDFs within each exposed sediment area would cover 17 acres in the former Plainwell Impoundment, 44 acres in the former Otsego Impoundment, and 60 acres in the former Trowbridge Impoundment, leaving a total of 389 acres of exposed sediment that would be covered with a 1-foot soil cap. It should be noted that the exposed sediment currently has a well-established vegetative cover, and any PCB contributions to the river from these areas during periods of inundation are expected to be small. Generally, the exposed sediments lie within the area defined by the former impoundment water elevations when the associated dam structures were at their full height. The thickness of the former sediments ranges from several inches in the areas at the upstream end to several feet in areas near the current dam sills. The average thicknesses of the former sediments are estimated at 3.8, 4.4, and 3.1 feet within the former Plainwell, Otsego and Trowbridge Impoundments, respectively. The former sediments have the appearance of gray clay and silt. Brown to light brown and orange sand and silt native soil exists beneath the exposed sediments and at the surface at higher elevations outside the former impoundment boundaries.

Although covering all of the exposed sediments/soils in the former impoundments is not necessary to address any remedial goals for the Site, it is assumed that the soil cover placement would proceed concurrent with the bank stabilization activities. Since the exposed sediments are generally immediately adjacent to the riverbanks, the access roads and other infrastructure constructed for bank stabilization would also be used for constructing the soil cover. The placement of the soil cover would generally begin as soon as the access areas and access roads for the bank stabilization activities are constructed, and could continue throughout the winter, since construction could be easier on the frozen ground. This would allow for staging of cover materials and cover placement activities to start from the already constructed access areas and roads. About one foot of sand and gravel would be placed over the exposed sediments and existing vegetation in the former impoundments, and the surface revegetated at the end of the project by direct seeding or hydroseeding. Established trees would not be removed; soil would be placed around the trunks. These measures would be taken to maintain the existing rootmass that currently provides significant physical stability and mitigates surficial erosion of PCB-containing exposed sediments. It is expected that geotextile/geogrids would be needed for in areas where the existing soils will not support construction activities. Alternatively, it may be possible to place soil in these areas during winter over frozen ground.

Work areas for the soil cover would be isolated by the installation of silt containment systems consisting of hay bales and silt fences. In addition, a floating, marine-type curtain would be used during bank stabilization activities. In order to place the cover materials on the exposed sediments on several small islands that are present within the open water of the former impoundments, materials would be loaded into scows and transported to the work areas. Temporary staging areas would be constructed at each of these work areas. Temporary docks constructed for bank stabilization activities would be used for mooring and launching scows and barges.

During bank stabilization and soil cover placement activities, the water column would be monitored for turbidity to evaluate the effectiveness of the silt curtain. As in Alternatives 3, 4, and 5, post-implementation monitoring would be performed to assess the need for maintenance.

Following completion of the second-pass dredging, the dam sills at the three former impoundments would be removed. Removal of the dam sills would be the last step in the construction process since water levels would be lowered by five to ten feet; this would potentially complicate dredging efforts and would lead to the release of PCB-containing sediment if dredging were not completed prior to sill removal. Construction activities to remove the dam sills would include use of a hydraulic hammer attached to a backhoe or other heavy machinery. Removals would be conducted in increments to prevent sudden release of remaining sediments behind the dam sills. The dam sill removal activities would be scheduled to occur during late-summer months, when river flow conditions are generally the lowest of the year. Resulting construction rubble may be used for local stream bank stabilization as required, or disposed of within any of the CDFs used for sediment consolidation and disposal. After removal of the dam sills, some minor shaping of riverbeds and adjacent banks would be required to match surrounding contours. The new riverbanks would be seeded and mulched, and additional cover vegetation or trees added.

Implementation Issues

If the siting of a CDF within each former impoundment area proves to be unacceptably difficult, the conceptual plan presented here could be altered to use a mechanical dredging operation and off-site disposal. In this situation, a mechanical dredge and support equipment would be used to dredge the submerged sediments from the former impoundment areas. The access roads built to facilitate bank stabilization activities would be used to provide staging areas for the land-based aspects of this approach. Mechanically-dredged materials would be transferred from the river to shore by scows, where they would be stockpiled in temporary dewatering lagoons (similar in size and construction to CDFs).

Stockpiled dredged materials would be rehandled from the dewatering lagoons, blended with stabilizing agents (e.g., kiln dust, fly ash) as necessary, and mechanically dewatered with belt filter presses. The dewatered materials would be loaded into trucks and hauled to a local solid waste landfill for final disposal. If the PCB concentration of the material is above 50 milligrams per kilogram (mg/kg), it will need to be transported to a Toxic Substances Control Act (TSCA)-approved facility for disposal. Water removed from the lagoons and the belt filter presses would be treated at on-site treatment facilities and returned to the river.

The mechanical dredging-based approach would be slower and more expensive than the hydraulic dredging plan discussed here, due to the added steps of dredged material rehandling and dewatering, and the additional tipping fees that would be incurred at the landfill. While some savings would be possible due to a reduction in the amount of water entrained during the dredging process, it must be recognized that a significant quantity of water will still require treatment due to the need to render the dredged material sufficiently dry for acceptance at the landfill.

A CDF is a commonly-constructed technology for dewatering and containing dredged sediments. The introduction of PCB into a CDF adds an additional degree of complexity, and will likely require the use of synthetic liners, drainage layers, surface capping, and groundwater monitoring wells, which are not typically a part of CDF design. Since PCB typically adsorbs tightly to soil and sediment particles, it is not likely that PCB would migrate from the CDF; however, the CDF liners may be required to satisfy certain regulatory design requirements. Construction of the three CDFs will require significant amounts of local borrow material, sand, and final cap materials.

The water treatment unit processes of flocculation, sedimentation, multimedia filtration, and activated carbon adsorption are all established technologies, even for treatment rates in the range of 3 to 6 MGD. However, the variability of water generation rates and slurry composition, coupled with the anticipated low effluent discharge standards (especially problematic during the last few years of operation, when increased flow rates to the CDFs will coincide with the CDFs approaching design capacity, while having less buffering ability to attenuate large quantities of water) would likely cause problems that could potentially result in schedule delays. As a result, it may be necessary to slow down the dredging operations to accommodate water treatment processes as the CDFs begin to approach storage capacity.

Community and Agency Acceptance

Community receptivity presents an implementability concern for a project of this magnitude. The significant destruction of land and water habitats to support the CDFs and the dredging activities, remediation work traffic, noise associated with the project, and disruption of recreational use of the river will likely draw strong opposition from the local community. Since the Site is designated as a CERCLA site, permits are not required for on-Site activities. However, the substantive and applicable requirements of Federal and State regulations would need to be met, as discussed in the FS.

Long-Term Impacts

Impacts to habitat and biota will result from dredging of submerged sediments and from the change in water levels and flow that would result from dam sill removal. Dam sill removal is likely to cause significant loss of upstream wetland habitat due to decreased water levels, as well as loss of in-stream benthic and fish habitat as a result of increased stream channelization and flow. Dredging will affect approximately 9 river miles of in-river habitat and a minimum of 136 acres of wetland or terrestrial habitat (CDF area only – estimate does not include access roads or staging areas). Long-term aquatic impacts from dredging include the complete destruction of present benthic and fish habitat and homogenization of in-river substrate. Wetland and terrestrial impacts are associated with the construction of CDFs, access roads, and staging areas. Impacts associated with access roads and staging areas would be mitigated by implementing restoration measures; however, CDFs will remain in place post-remediation. Thus, some degree of recovery of aquatic and terrestrial habitat would be expected, but significant ecological impacts associated with dam removal and dredging within the former impoundments are still expected for existing habitat and biota.

In addition to the effects of dredging and dam removal, aquatic biota will be adversely affected by the destruction of stream bank and riparian vegetation associated with bank stabilization, exposed sediment cover, and general access road construction. This vegetation provides valuable stream cover that helps maintain and balance the productivity of the aquatic community. Although the aquatic community would be negatively impacted in the short-term from the removal of large woody debris associated with bank stabilization, the restoration efforts proposed as a part of the bank stabilization alternative would mitigate these impacts. In general, restoration measures will include revegetation of banks and access roads, and replacement of large woody debris. While these aquatic impacts would still be realized in the short term (e.g., 5 years), they would be significantly mitigated by the proposed restoration measures in the long term.

While some of the impacts to aquatic and terrestrial habitat and biota associated with this conceptual plan are expected to be short-term and/or mitigated by restoration measures, negative long-term impacts associated specifically with dredging and dam removal would be expected for aquatic, wetland, and terrestrial habitat and biota.

Cost

The total estimated cost of implementing the dredging, dewatering, bank stabilization, exposed soil covering and dam sill removal as described in this conceptual plan is $397,120,000. Further details regarding costs are presented in Tables 1 and 2.

Tables

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
DREDGING OF SUBMERGED SEDIMENTS, EXPOSED SEDIMENT SOIL COVER, BANK STABILIZATION AND REMOVAL OF DAM SILLS AT THE FORMER IMPOUNDMENTS WITH CONFINED DISPOSAL AT EXPOSED SEDIMENT LOCATIONS, INSTITUTIONAL CONTROLS, AND MONITORING

Item No.	Remedial Component	Quantity	Units	Unit Cost	Item Cost
A	**Pass 1 Construction**				
	Mobilization - 1	1	lump sum	$928,000	$928,000
	General Conditions	1	lump sum	$696,000	$696,000
	Project Insurance	1	lump sum	$464,000	$464,000
	Construction Trailers	24	month	$400	$10,000
	Clearing	105,000	linear foot	$21	$2,205,000
	Access road construction/restoration	247,000	square yard	$27	$6,669,000
	CDF A = 17.2 Acres	- -	- -	- -	- -
	CDF B = 43.7 Acres	- -	- -	- -	- -
	CDF C = 60.5 Acres	- -	- -	- -	- -
	CDF Land lease or purchase	136	acre	$8,000	$1,088,000
	CDF clearing & grubbing	136	acre	$7,700	$1,047,000
	CDF bedding	195,889	cubic yard	$20	$3,918,000
	CDF exterior dikes	710,044	cubic yard	$15	$10,651,000
	CDF interior dikes	597,914	cubic yard	$15	$8,969,000
	CDF liner, bot & walls	5,289,011	square foot	$0.50	$2,645,000
	CDF piping	51,565	linear foot	$12	$614,000
	CDF monitoring wells	17	well	$1,000	$17,000
	WTF site preparation & paving	72,600	square yard	$25	$1,815,000
	WTF coagulation/flocculation/sedimentation	3	lump sum	$656,000	$1,968,000
	WTF multimedia filters	3	lump sum	$474,000	$1,422,000
	WTF carbon adsorption	3	lump sum	$545,000	$1,635,000
	WTF control buildings	4,500	square foot	$70	$315,000
	WTF misc pumps, piping & electrical	1	lump sum	$1,431,000	$1,431,000
	SUBTOTAL				$48,507,000
	Engineering/Project Management (8%)				$3,881,000
	Construction Oversight (6%)				$2,910,000
	Contingency (20%)				$9,701,000
				TOTAL (YEARS 2005 - 2006):	$64,999,000
				PRESENT VALUE:	$46,343,000

(See notes on page 4)

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
DREDGING OF SUBMERGED SEDIMENTS, EXPOSED SEDIMENT SOIL COVER, BANK STABILIZATION AND REMOVAL OF DAM SILLS AT THE FORMER IMPOUNDMENTS WITH CONFINED DISPOSAL AT EXPOSED SEDIMENT LOCATIONS, INSTITUTIONAL CONTROLS, AND MONITORING

Item No.	Remedial Component	Quantity	Units	Unit Cost	Item Cost
B	**Pass 1 Field Operations**				
	Dredging mobilization - 1	1	lump sum	$2,013,000	$2,013,000
	General Conditions	1	lump sum	$1,509,000	$1,509,000
	Project Insurance	1	lump sum	$1,006,000	$1,006,000
	Construction Trailers	60	month	$400	$24,000
	Dredges, barges, pumps and boats	10.0	crew-year	$700,726	$7,007,000
	Dredge, boat and pump fuel use	10.0	crew-year	$654,410	$6,544,000
	Dredge labor	10.0	crew-year	$1,303,584	$13,036,000
	Dredge pipelines	10.0	crew-year	$696,960	$6,970,000
	Silt Curtains, reefing and anchoring	10.0	crew-year	$123,000	$1,230,000
	Turbidity monitoring stations	1	lump sum	$2,431,000	$2,431,000
	Shoreline protection	1	lump sum	$5,095,000	$5,095,000
	Operate CDF - labor	2,786	day	$3,086	$8,599,000
	CDF & WTF maintenance	5	year	$1,770,000	$8,850,000
	WTF chemicals	7,850	m gal	$1,500	$11,775,000
	WTF filter media	7,850	m gal	$200	$1,570,000
	WTF activated carbon	7,850	m gal	$1,860	$14,600,000
	Operate WTF - labor	2,786	day	$4,629	$12,899,000
	SUBTOTAL				$105,158,000
	Engineering/Project Management (5%)				$5,258,000
	Construction Oversight (6%)				$6,309,000
	Contingency (20%)				$21,032,000
				TOTAL (YEARS 2006 - 2010):	$137,757,000
				PRESENT VALUE:	$80,543,000
C	**Pass 2 Construction**				
	CDF and WTF mobilization - 2	1	lump sum	$563,000	$563,000
	General Conditions	1	lump sum	$423,000	$423,000
	Project Insurance	1	lump sum	$282,000	$282,000
	Construction Trailers	48	Month	$400	$19,000
	Bank stab. & habitat enhancement - Plainwell	1	lump sum	$3,800,000	$3,800,000
	Bank stab. & habitat enhancement - Otsego	1	*lump sum*	$5,000,000	$5,000,000
	Bank stab. & habitat enhancemt - Trowbridge	1	lump sum	$13,325,000	$13,325,000
	WTF coagulation/flocculation/sedimentation	3	lump sum	$656,000	$1,968,000
	WTF multimedia filters	3	lump sum	$474,000	$1,422,000
	WTF carbon adsorption	3	lump sum	$545,000	$1,635,000
	WTF misc pumps, piping & electrical	1	lump sum	$1,005,000	$1,005,000
	SUBTOTAL				$29,442,000
	Engineering/Project Management (8%)				$2,355,000
	Construction Oversight (6%)				$1,767,000
	Contingency (20%)				$5,888,000
				TOTAL (YEARS 2007 - 2010):	$39,452,000
				PRESENT VALUE:	$17,247,000

(See notes on page 4)

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
DREDGING OF SUBMERGED SEDIMENTS, EXPOSED SEDIMENT SOIL COVER, BANK STABILIZATION AND REMOVAL OF DAM SILLS AT THE FORMER IMPOUNDMENTS WITH CONFINED DISPOSAL AT EXPOSED SEDIMENT LOCATIONS, INSTITUTIONAL CONTROLS, AND MONITORING

Item No.	Remedial Component	Quantity	Units	Unit Cost	Item Cost
D	**Pass 2 Field Operations**				
	Dredging mobilization - 2	1	lump sum	$522,000	$522,000
	General Conditions	1	lump sum	$392,000	$392,000
	Project Insurance	1	lump sum	$261,000	$261,000
	Construction Trailers	48	month	$400	$19,000
	Dredges, barges, pumps and boats	1.4	year	$805,351	$1,127,000
	Dredge, boat and pump fuel use	1.4	year	$1,034,570	$1,448,000
	Dredge labor	1.4	year	$1,303,584	$1,825,000
	Dredge pipelines	1.4	year	$760,320	$1,064,000
	Silt Curtains, reefing and anchoring	1.4	year	$123,000	$172,000
	Turbidity monitoring stations	1	lump sum	$306,000	$306,000
	Shoreline protection	1	lump sum	$711,000	$711,000
	Operate CDF - labor	389	day	$3,086	$1,201,000
	CDF & WTF maintenance	4	year	$2,072,000	$8,288,000
	WTF chemicals	2,292	m gal	$1,500	$3,439,000
	WTF filter media	2,292	m gal	$200	$458,000
	WTF activated carbon	2,292	m gal	$1,860	$4,264,000
	Operate WTF - labor	389	day	$4,629	$1,801,000
	SUBTOTAL				$27,298,000
	Engineering/Project Management (5%)				$1,365,000
	Construction Oversight (6%)				$1,638,000
	Contingency (20%)				$5,460,000
				TOTAL (YEARS 2007 - 2010):	$35,761,000
				PRESENT VALUE:	$20,179,000
E	**Closure Construction**				
	Mobilization - 3	1	lump sum	$1,078,000	$1,078,000
	General Conditions	1	lump sum	$809,000	$809,000
	Project Insurance	1	lump sum	$539,000	$539,000
	Construction Trailers	108	month	$400	$43,000
	Exposed soil cover & veget. - Plainwell	1	lump sum	$2,426,727	$2,427,000
	Exposed soil cover & veget. - Otsego	1	lump sum	$3,170,364	$3,170,000
	Exposed soil cover & veget. - Trowbridge	1	lump sum	$15,393,142	$15,393,000
	3 Dam Removals	3	lump sum	$1,000,000	$3,000,000
	Decommission water treat facilities	1	lump sum	$5,846,000	$5,846,000
	CDF top liner	4,287,252	square foot	$0.50	$2,144,000
	CDF cover material	476,361	cubic yard	$25	$11,909,000
	CDF 2% graded cap	398,797	cubic yard	$25	$9,970,000
	SUBTOTAL				$56,328,000
	Engineering/Project Management (8%)				$4,506,000
	Construction Oversight (6%)				$3,380,000
	Contingency (20%)				$11,266,000
				TOTAL (YEARS 2012 - 2020):	$75,480,000
				PRESENT VALUE:	$25,960,000
	SUBTOTAL DREDGING CONSTRUCTION				$179,931,000
	SUBTOTAL DREDGING OPERATION				$173,518,000
	SUBTOTAL DREDGING				$353,449,000
	SUBTOTAL PRESENT WORTH DREDGING CONSTRUCTION				$89,550,000
	SUBTOTAL PRESENT WORTH DREDGING OPERATION				$100,722,000
	SUBTOTAL PRESENT WORTH DREDGING				$190,272,000

(See notes on page 4)

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
DREDGING OF SUBMERGED SEDIMENTS, EXPOSED SEDIMENT SOIL COVER, BANK STABILIZATION AND REMOVAL OF DAM SILLS AT THE FORMER IMPOUNDMENTS WITH CONFINED DISPOSAL AT EXPOSED SEDIMENT LOCATIONS, INSTITUTIONAL CONTROLS, AND MONITORING

Item No.	Remedial Component	Quantity	Units	Unit Cost	Item Cost
F	**Annual Costs**	Years	Annual	Total	Present Worth
	Bathymetric surveys	(2006 - 2011)	$50,000	$300,000	$170,000
	Confirmation sampling and analyses	(2006 - 2020)	$832,000	$12,480,000	$5,403,000
	Bank observation	(2010 - 2040)	$36,129	$1,120,000	$246,000
	Bank maintenance	(2010 - 2040)	$479,548	$14,866,000	$3,269,000
	Monitoring - biota	(2006 - 2041)	$142,306	$5,123,000	$1,323,000
	Monitoring - water & sed	(2006 - 2041)	$132,111	$4,756,000	$1,228,000
	KALSIM model updates	(2006 - 2041)	$123,000	$4,428,000	$1,143,000
	CDF & groundwater monitoring	(2007 - 2050)	$13,591	$598,000	$123,000
	SUBTOTAL ANNUAL				$1,809,000
	SUBTOTAL ANNUAL ALL YEARS				$43,671,000
	SUBTOTAL ANNUAL PRESENT WORTH ALL YEARS				$12,905,000
				GRAND TOTAL COST:	**$397,120,000**
				GRAND TOTAL PRESENT WORTH COST:	**$203,177,000**

NOTES/ASSUMPTIONS

General:

- All costs include material and labor, unless otherwise noted.
- *Costs do not include legal fees, permitting, obtaining access, negotiations, or agency oversight.*
- Unit costs are in 2000 dollars and are estimated from standard estimating guides (e.g., Means Site Work and Landscape Cost Data, vendors, professional judgement and experience from other similar projects).
- *Costs based on current site information and project understanding. This may change following collection of additional data and/or receipt of* Agency input and actual project design.
- Cost estimates are generally developed based on the USEPA guidance document "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study", EPA 540-R-00-002 (OSWER 9355.0-75) dated July 2000.
- Present worth is estimated based on a 7 percent (%) beginning-of-year discount rate (adjusted for inflation) in accordance with USEPA policy directive entitled "Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis," OSWER Directive No. 9355.3-20 (USEPA, 1993). It is assumed that Year 0 is 2000.
- Engineering fees, project management and construction management are generally based on percentages shown on Exhibit 5-8 of the USEPA guidance document for feasibility study (OSWER 9355.0-075).
- A 20% contingency allowance is included to provide for unforeseen circumstances or variability in estimated areas, volumes, labor and material costs.

Specific:

- Mobilization/demobilization is a lump sum based on project size.
- General conditions refer to contractor overhead, and miscellaneous costs such as health and safety and construction trailer facility. Cost is a lump sum based on project size.
- Labor prices in accordance with Prevailing Rate Schedule, Kalamazoo Co., 1/1/2000 at 40hrs/wk/shift straight time and 14hrs overtime/wk/shift.
- Access area development includes clearing and preparation of equipment and material staging/handling areas. Restoration includes the removal and disposal of gravel, fill replacement, where necessary, followed by topsoil and vegetation.
- Access road construction assumes construction and restoration of a 16-foot wide roadway along both sides of the former impoundments, along one side of the in-between stretches and as needed to access the current impoundments, as further described in Alternatives 3 and 4 .
- *Bank Stabilization costs as described for Alternatives 3 and 4, including components for Plainwell, Otsego, and Trowbridge Impoundments.*
- Dredging by hydraulic cutterhead dredge, assuming 600 cy/day production when dredging in the Kalamazoo River and 2000 cy/day production when dredging in Lake Allegan. A second overdredge of a 6-inch layer is assumed for all areas.
- Cost of 13" Cutterhead Dredge at $2,400,000 amortized at 7.0% for 15-year life results in annual owner cost of $263,507.
- Dual layer vinyl coated polyester silt curtain includes reefing and anchoring. It is assumed that 3800 linear feet will be replaced yearly. Silt curtain based on Elastec quotation, 9/98 escalated to 1/00.
- Five real-time turbidity monitoring stations are used for each dredging segment. Fixed monitoring stations are constructed of 6-in steel piling for each dredging segment, and removed after dredging. It is assumed that turbidity sensors will be replaced every 90,000 cy of dredging.

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
PRELIMINARY COST ESTIMATE
DREDGING OF SUBMERGED SEDIMENTS, EXPOSED SEDIMENT SOIL COVER, BANK STABILIZATION AND REMOVAL OF DAM SILLS AT THE FORMER IMPOUNDMENTS WITH CONFINED DISPOSAL AT EXPOSED SEDIMENT LOCATIONS, INSTITUTIONAL CONTROLS, AND MONITORING

- Sheet piling will be placed along certain stretches to protect onshore facilities from dredging disturbance. It is assumed that this will be required along 10 percent of the shoreline.
- Cost of Boat at $350,000 amortized at 7.0% for 10-year life results in annual owner cost of $49.832.
- Boat consumes total energy of 35 HP at Engine Fuel Factor (EFF) of 0.042 and fuel price of $1.80/ gal, for fuel costs of $2.65 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $0.265 per hr or $3.71 per day, for total fuel costs of $30 per day.
- 6 miles avg. pipeline reach
- First-pass dredging of Kalamazoo River segments at: 60 cy/hr; 10 hrs/day; 6 days/wk; 4 wk/mo; 10 mo/yr; 2400 hrs/yr; or 144,000 cy/yr
- In-situ solids = 77%; dredge solids = 5%; dredge slurry pumping rate = 12.9 cfs during 10-hr/day.
- Cost of 13" Cutterhead Dredge at $2,400,000 amortized at 7.0% for 15-year life results in annual owner cost of $263,507.
- 13" Cutterhead Dredge consumes total energy of 2630 HP at EFF of 0.042 and fuel price of $1.80/ gal, for fuel costs of $199 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $19.9 per hr or $279 per day, for total fuel costs of $2269 per day.
- Three 13-inch booster pumps consume total energy of 311 HP at EFF of 0.042 and fuel price of $1.80/ gal, for fuel costs of $24 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $2.4 per hr or $34 per day, for total fuel costs of $274 per day.
- Second-pass dredging of Kalamazoo River segments at: 60 cy/hr; 10 hrs/day; 6 days/wk; 4 wk/mo; 10 mo/yr; 2400 hrs/yr; or 144,000 cy/yr
- In-situ solids = 77%; dredge solids = 2.5%; dredge slurry pumping rate = 26.2 cfs during 10-hr/day.
- Cost of 18" Cutterhead Dredge at $3,900,000 amortized at 7.0% for 20-year life results in annual owner cost of $368,132.
- 18" Cutterhead Dredge consumes total energy of 4148 HP at EFF of 0.042 and fuel price of $1.80/ gal, for fuel costs of $314 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $31.4 per hr or $440 per day, for total fuel costs of $3580 per day.
- Three 18-inch booster pumps consume total energy of 630 HP at EFF of 0.042 and fuel price of $1.80/ gal, for fuel costs of $48 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $4.80 per hr or $67 per day, for total fuel costs of $547 per day.
- CDF area requirement is based on achieving long-term solids content of 47% w/w in facilities with 20-ft ultimate height. Three facilities are anticipated, with total containment volume of 2.5 million cy. Side slopes of 1:3 add additional area requirements, in addition to adjacent facilities for water treatment.
- CDF sizing is in accordance with Engineer Manual 1110-2-5027, Engineering and Design, Confined Disposal of Dredged Material, USACE (30 Sep 1987).
- CDFs are assumed to contain a sand bedding of 1-ft, underdrains and polyethylene lining, prior to commencement of operation. Sizing of the CDFs assume 8 internal dikes will be constructed to facilitate operation and consolidation of sediment.
- Water treatment for overflow of dredge water from the CDF consists of flocculation, sedimentation, dual-media filtration and activated carbon adsorption. Discharge is to the Kalamazoo River or Lake Allegan. Treatment facilities are located adjacent to each of the three CDFs. Unit costs are based on experience at the Fox River SMU 56/57, with elimination of neutralization chemical costs. Flocculation and sedimentation assume 60 min. detention, filtration facilities are assumed to be loaded at 2.0 gpd/sf, and carbon contactors assume empty bed contact time of
- Control building of 1500 square ft to be constructed for each WTF.
- Closure of completed CDFs, after five years of final consolidation, would consist of a polyethylene membrane, one foot of soil cover and a 2%-sloped soil cap for runoff control.
- Bathymetric surveys are performed annually during dredging to confirm effectiveness.
- Confirmation Sampling includes analyses and QA/QC for in-situ sediments, waters and residuals for dredging and water treatment operations.
- Construction oversight includes project management and daily reports.
- Engineering fees are based on 8% of the construction subtotal cost or 5% of operational costs during field execution.
- Contingency is based upon 20% of the construction subtotal cost.
- Present worth dredging and disposal cost assumes costs are spread evenly over the duration of each program segment, at a 7% discount rate.
- Present worth cost includes institutional controls and monitoring. Samples for Advisory Monitoring of Biota are taken at year 1, then every 5 years until 30 years after completion of dredging. Samples for Trend Monitoring of Biota are taken at year 1, then every 3 years until 30 years after completion of dredging. Water and sediment samples are taken at year 1, then every 5 years until 30 years after completion of dredging. KALSIM model updates are performed at year 1, then every 5 years until 30 years after completion of dredging.
- Annual costs for maintenance of restored impoundments as developed for Alternative 3.
- CDF monitoring consists of sampling and analyses of perimeter monitoring wells for 52 years.
- Total present worth cost is the sum of costs for dredging, disposal, water treatment, institutional controls, and monitoring.

TABLE 2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
DREDGE COST ASSUMPTIONS
DREDGING OF SUBMERGED SEDIMENTS, EXPOSED SEDIMENT SOIL COVER, BANK STABILIZATION AND REMOVAL OF DAM SILLS AT THE FORMER IMPOUNDMENTS WITH CONFINED DISPOSAL AT EXPOSED SEDIMENT LOCATIONS, INSTITUTIONAL CONTROLS, AND MONITORING

SEGMENTS A1 & B1 & C1

- First-pass dredging of Kalamazoo River segments at 60 cy/hr, 10 hrs/day; 6 days/wk; 4 wk/mo; 10 mo/yr, 2400 hrs/yr; or 144,000 cy/yr
- In-situ solids = 77%; dredge solids = 5%, dredge slurry pumping rate = 12.9 cfs during 10-hr/day.
- Dredge sizing to maintain pipeline velocity of 15 fps is 12.6 inches; therefore select 13-inch dredge.

Equipment and Operating Costs

	Item	No.	Units	Unit cost	(Annual) Tot cost
1	13" Cutterhead Dredge	240	days	$1,098	$263,507
2	Boat	240	days	$208	$49,832
2	Boat	240	days	$208	$49,832
3,4	Fuel	240	days	$2,331	$559,320
5	Dredge operator (3 shifts/day)	40	weeks	$5,905	$236,201
6	Engineer (3 shifts/day)	40	weeks	$5,779	$231,142
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
2	Barge for debris	240	days	$59	$14,238
2	Barge for debris	240	days	$59	$14,238
2	Boat, debris crew	240	days	$208	$49,832
4	Fuel	240	days	$31	$7,440
2	Boat, debris crew	240	days	$208	$49,832
4	Fuel	240	days	$31	$7,440
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
8	Silt Curtains, reefing and anchoring	3,800	LF/yr	$32	$123,000
2	Boat	240	days	$208	$49,832
4	Fuel	240	days	$30	$7,200
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
9	3 Booster pumps and barges	240	days	$457	$109,751
10	Booster pump fuel	240	days	$274	$65,760
11	13" Pipeline	31,680	LF/yr	$22	$696,960
2	Boat	240	days	$208	$49,832
4	Fuel	240	days	$30	$7,250
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
				Total:	$3,478,681
				Total $/cy dredged:	$24 16

Notes

1 Cost of 13" Cutterhead Dredge at $2400000 amortized at 7.0% for 15-year life results in annual owner cost of $263,507.

2 Cost of Boat at $350 000 amortized at 7.0% for 10-year life results in annual owner cost of $49,832.

3 13" Cutterhead Dredge consumes total energy of 2630 HP at Engine Fuel Factor (EFF) of 0.042 and fuel price of $1.8/ gal, for fuel costs of $199 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $19.9 per hr or $279 per day, for total fuel costs of $2269 per day.

4 Boat consumes total energy of 35 HP at Engine Fuel Factor (EFF) of 0.042 and fuel price of $1.8/ gal, for fuel costs of $2.65 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $0.265 per hr or $3.71 per day, for total fuel costs of $30 per day.

5 Crane engineer, Prevailing Rate Schedule, Kalamazoo Co., 1/1/2000 at 33 35$/hr, straight for 40hrs/wk/shift and 45.31$/hr, ot for 14hrs ot/wk/shift, resulting in 1,968.34$/wk/shift or 5,905 02$/wk for 3 shifts.

6 Class I engineer, Prevailing Rate Schedule, Kalamazoo Co., 1/1/2000 at 32.66$/hr, straight for 40hrs/wk/shift and 44 27$/hr, ot for 14hrs ot/wk/shift, resulting in 1,926 18$/wk/shift or 5,778.54$/wk for 3 shifts.

7 Laborer Class B, Prevailing Rate Schedule, Kalamazoo Co., 1/1/2000 at 22 52$/hr, straight for 40hrs/wk/shift and 32.43$/hr, ot for 14hrs ot/wk/shift, resulting in 1,354 82$/wk/shift or 4,064 46$/wk for 3 shifts. Debris crew at 10 hrs/day or 40 hrs straight time and 20 hrs ot per week

8 Elastec quotation, 9/98 escalated to 1/00, replace yearly.

9 Cost of 3 Booster pumps and barges at $450 000 amortized at 7.0% for 5-year life results in annual owner cost of $109,751

10 Three 13-inch booster pumps consume total energy of 311 HP at EFF of 0.042 and fuel price of $1.8/ gal, for fuel costs of $24 per hour for 10 active hours per day, while idling 14 hrs per day, fuel costs are $2 4 per hr or $34 per day, for total fuel costs of $274 per day

11 6 miles avg pipeline reach

TABLE 2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
DREDGE COST ASSUMPTIONS
DREDGING OF SUBMERGED SEDIMENTS, EXPOSED SEDIMENT SOIL COVER, BANK STABILIZATION AND REMOVAL OF DAM SILLS AT THE FORMER IMPOUNDMENTS WITH CONFINED DISPOSAL AT EXPOSED SEDIMENT LOCATIONS, INSTITUTIONAL CONTROLS, AND MONITORING

SEGMENTS A2 & B2 & C2

- Second-pass dredging of Kalamazoo River segments at. 60 cy/hr; 10 hrs/day; 6 days/wk; 4 wk/mo. 10 mo/yr; 2400 hrs/yr; or 144000 cy/yr
- In-situ solids = 77%. dredge solids = 2 5%; dredge slurry pumping rate = 26 2 cfs during 10-hr/day
- Dredge sizing to maintain pipeline velocity of 15 fps is 17.9 inches; therefore select 18-inch dredge

Equipment and Operating costs

	Item	No.	Units	Unit cost	(Annual) Tot cost
1	18" Cutterhead Dredge	240	days	$1,534	$368,132
2	Boat	240	days	$208	$49,832
2	Boat	240	days	$208	$49,832
3,4	Fuel	240	days	$3,642	$873,960
5	Dredge operator (3 shifts/day)	40	weeks	$5,905	$236,201
6	Engineer (3 shifts/day)	40	weeks	$5,779	$231,142
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
2	Barge for debris	240	days	$59	$14,238
2	Barge for debris	240	days	$59	$14,238
2	Boat, debris crew	240	days	$208	$49,832
4	Fuel	240	days	$31	$7,440
2	Boat, debris crew	240	days	$208	$49,832
4	Fuel	240	days	$31	$7,440
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
7	Laborer (1 shift/day), debris	40	weeks	$1,549	$61,976
8	Silt Curtains, reefing and anchoring	3,800	LF/yr	$32	$123,000
2	Boat	240	days	$208	$49,832
4	Fuel	240	days	$30	$7,200
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
9	3 Booster pumps and barges	240	days	$457	$109,751
10	Booster pump fuel	240	days	$547	$131,280
11	18" Pipeline	31,680	LF/yr	$24	$760,320
2	Boat	240	days	$208	$49,832
4	Fuel	240	days	$30	$7,250
7	Laborer (3 shifts/day)	40	weeks	$4,064	$162,578
				Total:	$4,026,826
				Total $/cy dredged:	$27 96

Notes

1 Cost of 18" Cutterhead Dredge at $3,900,000 amortized at 7.0% for 20-year life results in annual owner cost of $368,132.

2 Cost of Boat at $350,000 amortized at 7 0% for 10-year life results in annual owner cost of $49,832.

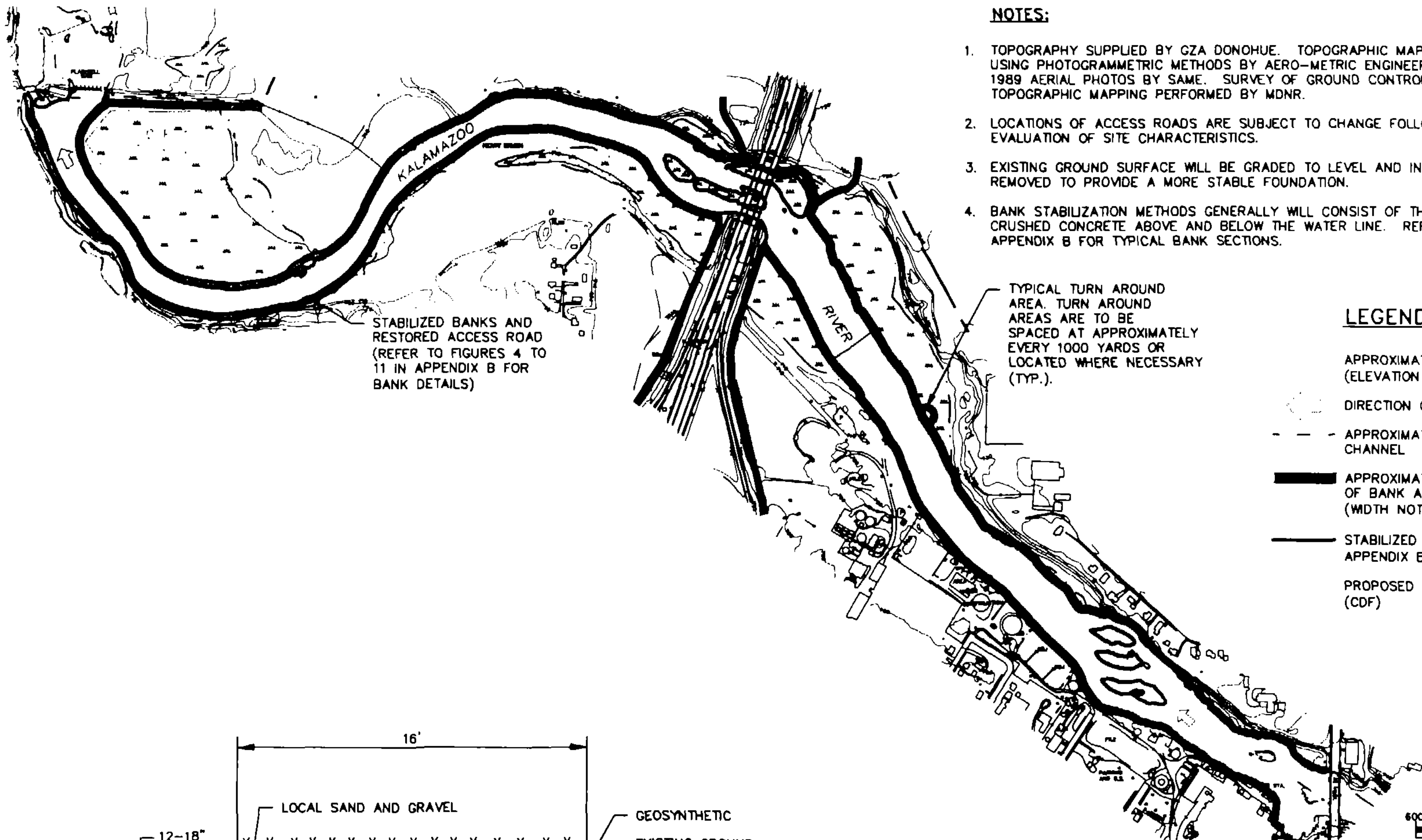
3 18" Cutterhead Dredge consumes total energy of 4148 HP at EFF of 0.042 and fuel price of $1 8/ gal, for fuel costs of $314 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $31.4 per hr or $440 per day, for total fuel costs of $3,580 per day.

9 Cost of 3 Booster pumps and barges at $450,000 amortized at 7 0% for 5-year life results in annual owner cost of $109,751.

10 Three 18-inch booster pumps consume total energy of 630 HP at EFF of 0 042 and fuel price of $1 8/ gal, for fuel costs of $48 per hour for 10 active hours per day; while idling 14 hrs per day, fuel costs are $4.8 per hr or $67 per day, for total fuel costs of $547 per day

11 6 miles avg. pipeline reach

Figures



NOTES:

1. TOPOGRAPHY SUPPLIED BY GZA DONOHUE. TOPOGRAPHIC MAPPING PRODUCED USING PHOTOGRAMMETRIC METHODS BY AERO-METRIC ENGINEERING, INC. USING 1989 AERIAL PHOTOS BY SAME. SURVEY OF GROUND CONTROL POINTS FOR TOPOGRAPHIC MAPPING PERFORMED BY MDNR.
2. LOCATIONS OF ACCESS ROADS ARE SUBJECT TO CHANGE FOLLOWING A MORE COMPLETE EVALUATION OF SITE CHARACTERISTICS.
3. EXISTING GROUND SURFACE WILL BE GRADED TO LEVEL AND IN SOME AREAS, TOP SOIL WILL BE REMOVED TO PROVIDE A MORE STABLE FOUNDATION.
4. BANK STABILIZATION METHODS GENERALLY WILL CONSIST OF THE INSTALLATION OF RIPRAP OF CRUSHED CONCRETE ABOVE AND BELOW THE WATER LINE. REFER TO FIGURES 4 TO 11 IN APPENDIX B FOR TYPICAL BANK SECTIONS.

LEGEND

APPROXIMATE FORMER IMPOUNDMENT (ELEVATION 712)

DIRECTION OF FLOW

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

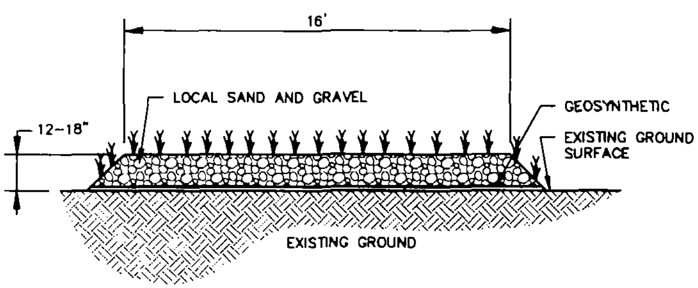
APPROXIMATE ANTICIPATED LOCATION OF BANK ACCESS ROAD (WIDTH NOT TO SCALE)

STABILIZED BANK (SEE FIGURES 4 TO 11 IN APPENDIX B FOR DETAILS)

PROPOSED CONFINED DISPOSAL FACILITY (CDF)

600' 0 600'

SCALE



RESTORED ACCESS ROAD WITH HABITAT ENHANCEMENTS

NOT TO SCALE

DRAFT

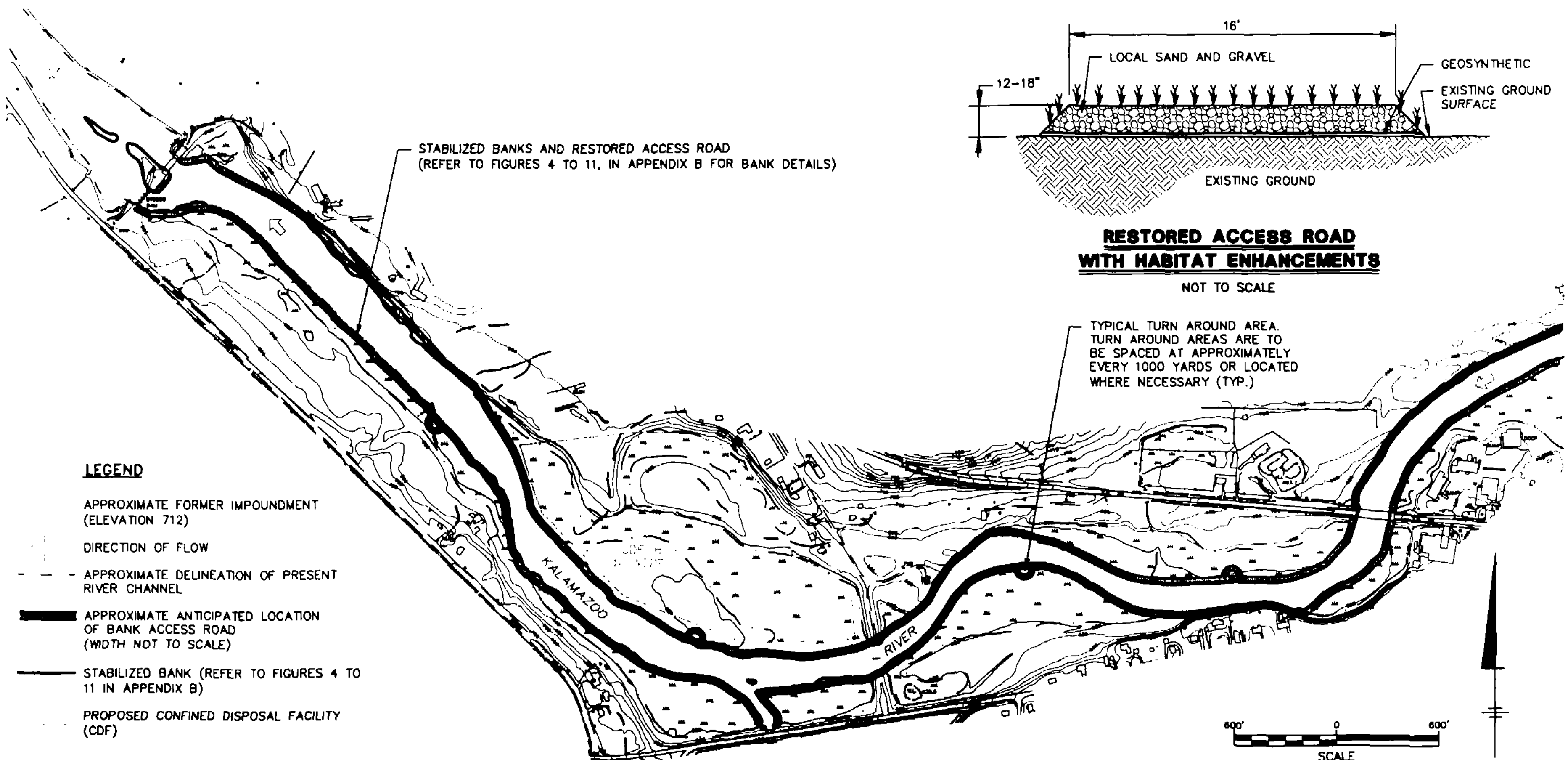
FOR STATE AND FEDERAL REVIEW

KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FEASIBILITY STUDY REPORT

FORMER PLAINWELL IMPOUNDMENT CONCEPTUAL PLAN FOR CDF LOCATION

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 1



RESTORED ACCESS ROAD
WITH HABITAT ENHANCEMENTS

NOT TO SCALE

LEGEND

APPROXIMATE FORMER IMPOUNDMENT (ELEVATION 712)

DIRECTION OF FLOW

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE ANTICIPATED LOCATION OF BANK ACCESS ROAD (WIDTH NOT TO SCALE)

STABILIZED BANK (REFER TO FIGURES 4 TO 11 IN APPENDIX B)

PROPOSED CONFINED DISPOSAL FACILITY (CDF)

NOTES:

1. TOPOGRAPHY SUPPLIED BY GZA DONOHUE. TOPOGRAPHIC MAPPING PRODUCED USING PHOTOGRAMMETRIC METHODS BY AERO-METRIC ENGINEERING, INC. USING 1989 AERIAL PHOTOS BY SAME. SURVEY OF GROUND CONTROL POINTS FOR TOPOGRAPHIC MAPPING PERFORMED BY MDNR.
2. LOCATIONS OF ACCESS ROADS ARE SUBJECT TO CHANGE FOLLOWING A MORE COMPLETE EVALUATION OF SITE CHARACTERISTICS.
3. EXISTING GROUND SURFACE WILL BE GRADED TO LEVEL AND IN SOME AREAS, TOP SOIL WILL BE REMOVED TO PROVIDE A MORE STABLE FOUNDATION.
4. BANK STABILIZATION METHODS GENERALLY WILL CONSIST OF THE INSTALLATION OF RIPRAP OF CRUSHED CONCRETE ABOVE AND BELOW THE WATER LINE. REFER TO FIGURES 4 TO 11 IN APPENDIX FOR TYPICAL BANK SECTIONS.

DRAFT
FOR STATE AND FEDERAL REVIEW

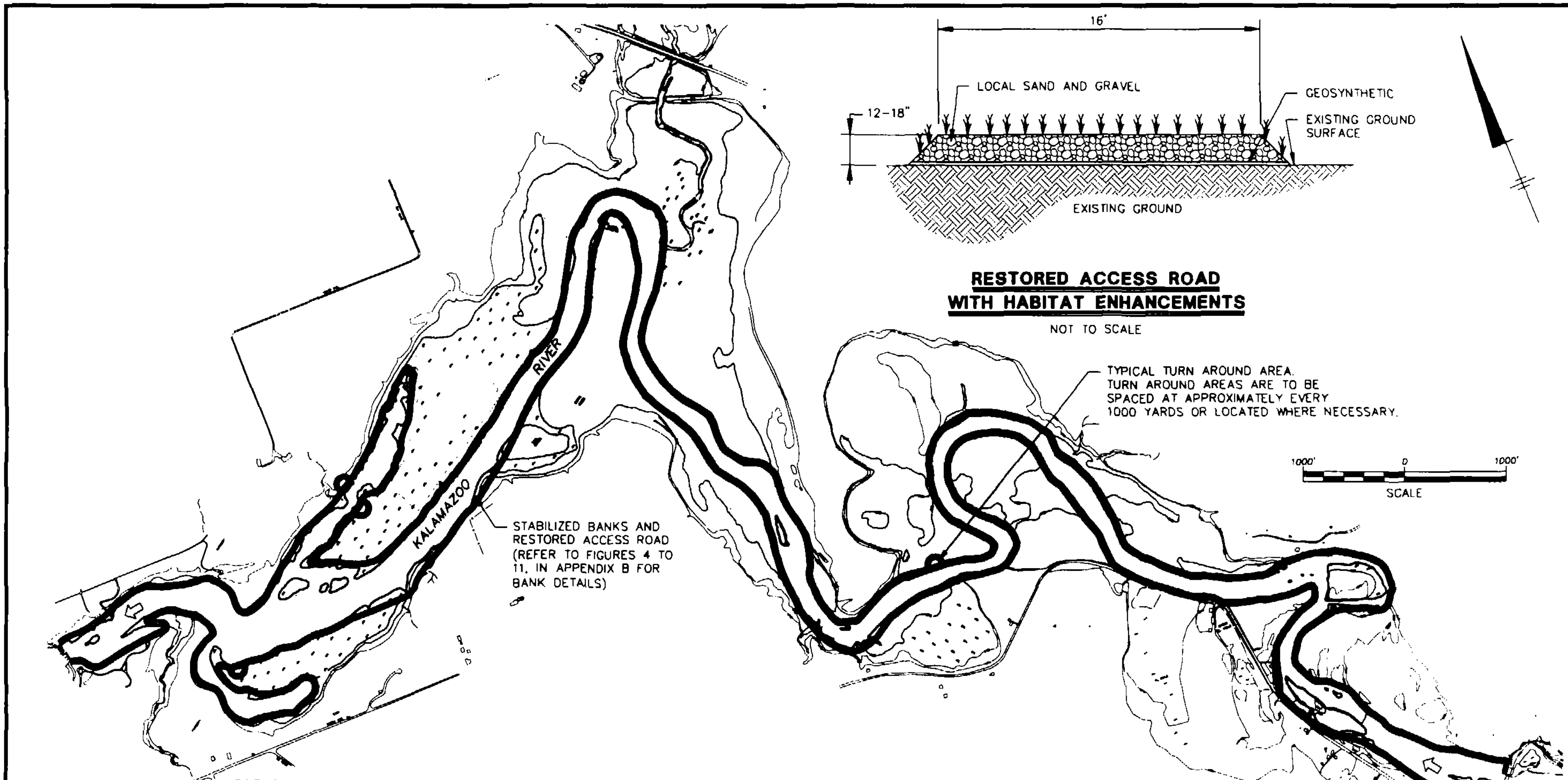
KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FEASIBILITY STUDY REPORT

FORMER OTSEGO IMPOUNDMENT CONCEPTUAL PLAN FOR CDF LOCATION

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 2

X: NONE P: STD-PCP/BL L: ON=* OFF=REF*
64524840/64524G09.DWG 10/27/00 SYR-54-KMD SDL KMD



LEGEND

APPROXIMATE FORMER IMPOUNDMENT (ELEVATION 712)

DIRECTION OF FLOW

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE ANTICIPATED LOCATION OF BANK ACCESS ROAD (WIDTH NOT TO SCALE)

STABILIZED BANK (REFER TO FIGURES 4 TO 11 IN APPENDIX B)

PROPOSED CONFINED DISPOSAL FACILITY (CDF)

NOTES:

1. TOPOGRAPHY SUPPLIED BY GZA DONOHUE. TOPOGRAPHIC MAPPING PRODUCED USING PHOTOGRAMMETRIC METHODS BY AERO-METRIC ENGINEERING, INC. USING 1989 AERIAL PHOTOS BY SAME. SURVEY OF GROUND CONTROL POINTS FOR TOPOGRAPHIC MAPPING PERFORMED BY MDNR
2. LOCATIONS OF ACCESS ROADS ARE SUBJECT TO CHANGE FOLLOWING A MORE COMPLETE EVALUATION OF SITE CHARACTERISTICS.
3. EXISTING GROUND SURFACE WILL BE GRADED TO LEVEL AND IN SOME AREAS, TOP SOIL WILL BE REMOVED TO PROVIDE A MORE STABLE FOUNDATION.
4. BANK STABILIZATION METHODS GENERALLY WILL CONSIST OF THE INSTALLATION OF RIPRAP OF CRUSHED CONCRETE ABOVE AND BELOW THE WATER LINE. REFER TO FIGURES 4 TO 11 IN APPENDIX B FOR TYPICAL BANK SECTIONS.

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FOR STATE AND FEDERAL REVIEW

KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE
FEASIBILITY STUDY REPORT

FORMER TROWBRIDGE IMPOUNDMENT CONCEPTUAL PLAN FOR CDF LOCATION

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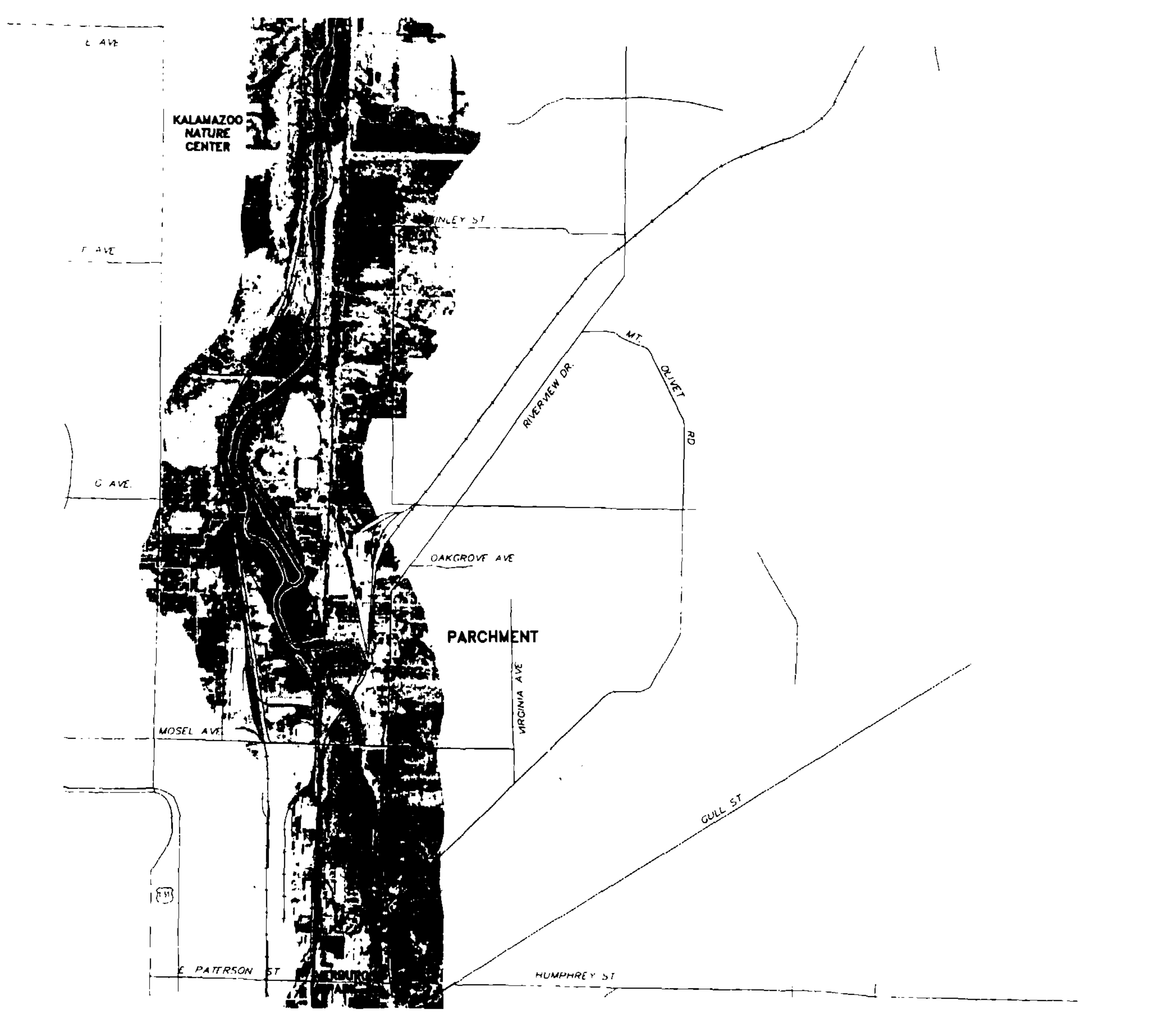
FIGURE 3

X: NONE
L: ON=*, OFF=REF*,SP-TOC
P: SPEC.PCP
11/2/00 SYR-54-KMD KMD CBM
64524640/64524G10.DWG



LEGEND

FLOW DIRECTION

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE BOUNDARY OF FORMER IMPOUNDMENT

6.0 APPROXIMATE RIVER MILES ALONG THE MAIN CHANNEL

TENTATIVE LOCATION OF ACCESS/SEDIMENT HANDLING AREA

APPROXIMATE LOCATION OF PROPOSED ACCESS ROAD AND STABILIZED BANKS

INDICATES LIMITED ACCESS, OR WHERE ACCESS WOULD BE DIFFICULT FOR WATER BASED CONSTRUCTION WORKS

NOTES:

1. PLANIMETRIC MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEMS.
2. AERIAL IMAGE DERIVED FROM ORTHOPHOTOGRAPHIC DATA BY AIR LAND SURVEYS, INC., FLOWN 4/24/99.

0 2400' 4800'

SCALE

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FOR STATE AND FEDERAL REVIEW

KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT

KALAMAZOO RIVER DOWNSTREAM OF THE PORTAGE CREEK CONFLUENCE

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 4

LEGEND

FLOW DIRECTION

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE BOUNDARY OF FORMER IMPOUNDMENT

11.0 APPROXIMATE RIVER MILES ALONG THE MAIN CHANNEL

TENTATIVE LOCATION OF ACCESS/SEDIMENT HANDLING AREA

APPROXIMATE LOCATION OF PROPOSED ACCESS ROAD AND STABILIZED BANKS

INDICATES LIMITED ACCESS, OR WHERE ACCESS WOULD BE DIFFICULT FOR WATER BASED CONSTRUCTION WORKS

NOTES:

1. PLANIMETRIC MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEMS.
2. AERIAL IMAGE DERIVED FROM ORTHOPHOTOGRAPHIC DATA BY AIR LAND SURVEYS, INC., FLOWN 4/24/99.

0 2400' 4800'

SCALE

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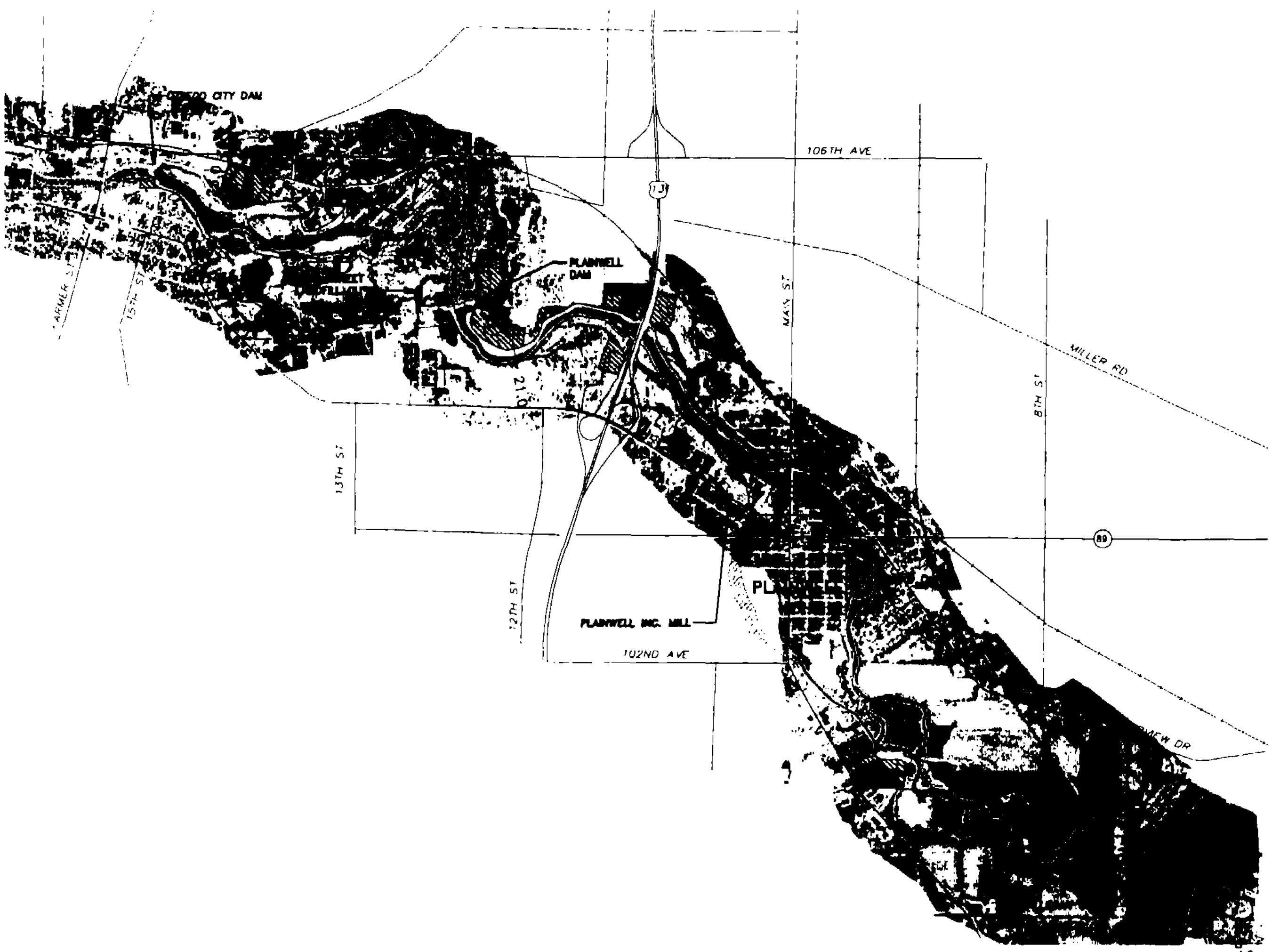
KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT

KALAMAZOO RIVER UPSTREAM OF PLAINWELL

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 5



LEGEND

FLOW DIRECTION

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE BOUNDARY OF FORMER IMPOUNDMENT

17.0 APPROXIMATE RIVER MILES ALONG THE MAIN CHANNEL

TENTATIVE LOCATION OF ACCESS/SEDIMENT HANDLING AREA

APPROXIMATE LOCATION OF PROPOSED ACCESS ROAD AND STABILIZED BANKS

INDICATES LIMITED ACCESS, OR WHERE ACCESS WOULD BE DIFFICULT FOR WATER BASED CONSTRUCTION WORKS

NOTES:

1. PLANIMETRIC MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEMS.
2. AERIAL IMAGE DERIVED FROM ORTHOPHOTOGRAPHIC DATA BY AIR LAND SURVEYS, INC., FLOWN 4/24/99.

0 2400' 4800'

SCALE

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FOR STATE AND FEDERAL REVIEW

KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT

FORMER PLAINWELL AND OTSEGO CITY IMPOUNDMENTS

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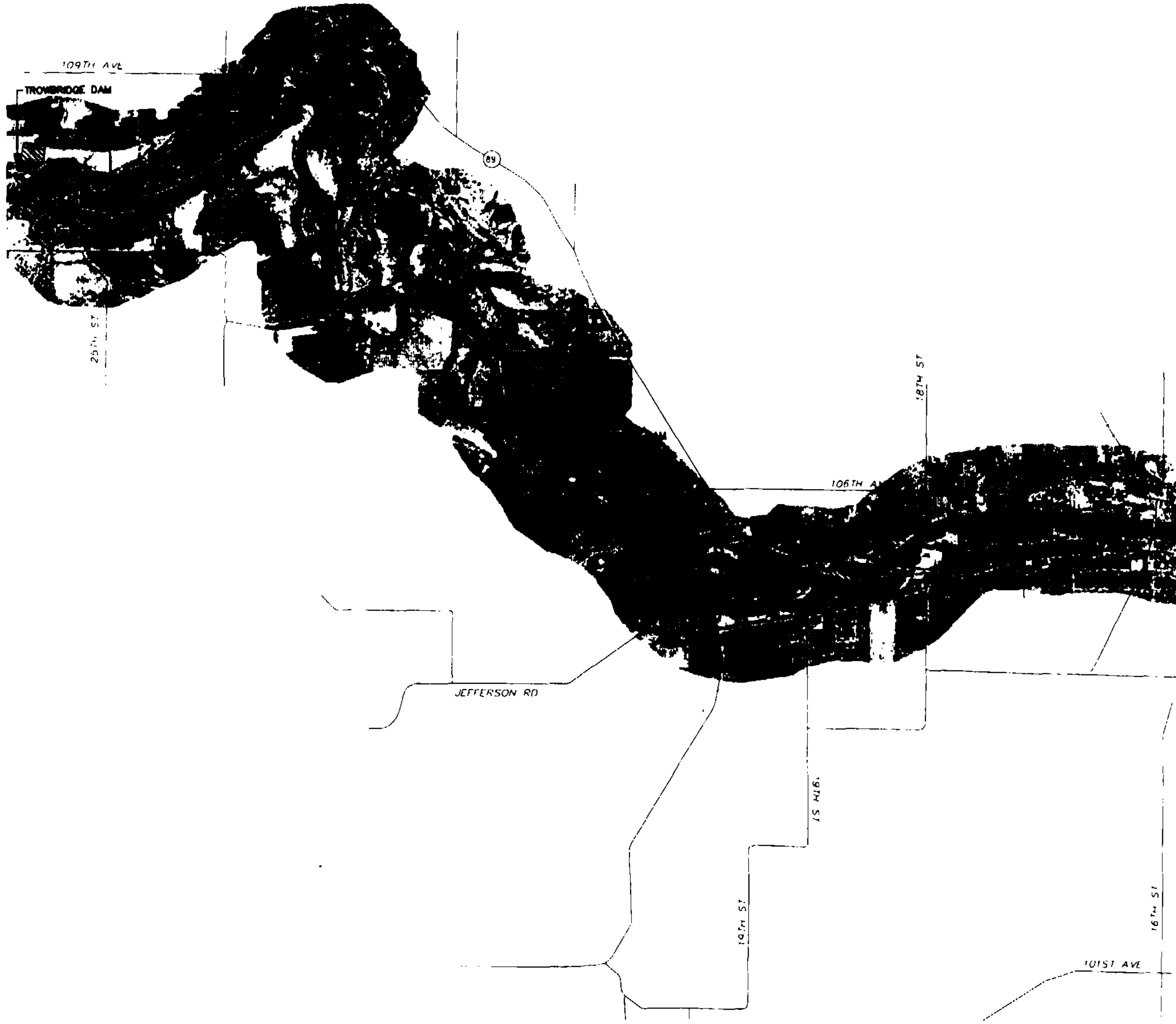
FIGURE 6



LEGEND

FLOW DIRECTION

APPROXIMATE DELINEATION OF PRESENT RIVER CHANNEL

APPROXIMATE BOUNDARY OF FORMER IMPOUNDMENT

24.0 APPROXIMATE RIVER MILES ALONG THE MAIN CHANNEL

TENTATIVE LOCATION OF ACCESS/SEDIMENT HANDLING AREA

APPROXIMATE LOCATION OF PROPOSED ACCESS ROAD AND STABILIZED BANKS

INDICATES LIMITED ACCESS, OR WHERE ACCESS WOULD BE DIFFICULT FOR WATER BASED CONSTRUCTION WORKS

NOTES:

1. PLANIMETRIC MAPPING OBTAINED FROM MICHIGAN RESOURCE INFORMATION SYSTEMS.
2. AERIAL IMAGE DERIVED FROM ORTHOPHOTOGRAPHIC DATA BY AIR LAND SURVEYS, INC., FLOWN 4/24/99.

0 2400' 4800'

SCALE

KALAMAZOO RIVER STUDY GROUP
ALLIED PAPER, INC /PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT

FORMER OTSEGO AND FORMER TROWBRIDGE IMPOUNDMENTS

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FIGURE 7

Appendix G

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Worker Risk Estimates

Appendix G – Worker Risk Estimates

1.0 Introduction

Workers at the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site (Site) will face physical risks during the implementation of any of the alternatives identified for remediation of river sediments and/or exposed sediments in the former impoundments that employ active remedial technologies. In particular, active remedies may pose the following implementation risks:

- accidents involving the operation of heavy equipment;
- accidents during excavation, dredging, transportation, and material processing; and
- accidents during off-site transportation.

The absence of quantitative data on historical accident frequency and consequence precludes estimation of the absolute level of risks to remediation workers; however, risks can be evaluated for each of the proposed active remedial alternatives by considering the requirements for manpower expenditures, earthwork and materials handling, and transportation. Based on a number of assumptions made during the development of costs for each of the potential remedial alternatives (see Section 4 of the Feasibility Study [FS]), a preliminary estimate of labor hours for intrusive activities was prepared. These estimates contain a number of uncertainties which could be further refined during remedial design, but are consistent with the level of accuracy generally attributed to FS-level cost estimates (i.e., -30/+50%). In addition, only the labor categories directly involved in field remedial activities were considered in this analysis; support services (e.g., accounting/purchase agents, secretarial staff, and surveyors) were not accounted for, thus underestimating the potential risks associated with each remedy. The labor hour estimates used in this assessment of risks for eleven general categories of workers are provided in Table 1.

The probability of fatal accidents occurring during the implementation of any of the active remedial alternatives, estimated based on readily available occupational employment fatality data and the labor estimates presented in Table 1, can be used to develop a quantitative assessment of accident-related risks associated with the implementation of the active remedial alternatives. In conducting this evaluation, it is assumed that fatal accident rates associated with the remediation of hazardous waste sites are equivalent to accident rates associated with similar activities at construction sites (Hoskin et al., 1994). Specifically, data for fatal occupational injuries associated with the construction industry labor categories similar to those labor categories identified for implementing the remedial alternatives (e.g., equipment operator, laborer, inspector) are used to estimate the risk of having at least one fatal injury occur during the remedy implementation.

The use of construction site accident rates as a surrogate for risks at hazardous waste sites is necessary because fatality rates are not available for the hazardous waste remediation industry. Since hazardous waste site remediation is likely to be more dangerous than the average industry (Leigh and Hoskin, 1999), the use of construction site data is expected to underestimate the risk to hazardous waste site workers. For example, according to an U.S. Army study on risks associated with chemical munitions disposal, fork lift accident frequency is anticipated to be five times higher for workers in personal protective equipment (PPE) levels B and C compared with workers in level D PPE (U.S. Army, 1987).

2.0 Approach

As described above, short-term risks associated with the implementation of the remedial alternatives can be evaluated using information on the frequency of fatal occupational injuries for related activities (e.g., construction laborers, excavation equipment operators, etc.) using an approach developed by Hoskin et al. (1994). First, work-related death rates for the occupations identified in the labor estimates listed in Table 1 were obtained from the U.S. Bureau of Labor Statistics (BLS). Then the annual death rate for each occupation is calculated as the number of deaths in a given year divided by the estimated number of persons employed in that occupation in that year. Next, each occupation's annual death rate is multiplied by a weighting function – the percentage of the total labor hours associated with the remediation project for that occupation (Hoskin et al., 1994). Then, all the weighted annual death rates are averaged together to arrive at an overall rate of occupational fatalities associated with the remediation project. Multiplying the overall weighted fatality rate by the total person-years of labor for a project yields the number of expected fatalities associated with the project. The risk of a fatality is then computed as the probability of experiencing at least one fatality, assuming that the injury-producing process follows a Poisson distribution. That is, assuming that the incidence of fatal injuries follows a Poisson distribution, the number of fatal injuries predicted by the overall fatality rate is equal to the mean of the Poisson distribution (Hoskin et al., 1994):

- Expected number of fatalities (u) = (worker-years of exposure)(weighted fatality rate)

  where the total worker-years of exposure is equal to the total estimated time (person-years) for a implementing a specific remedy.

- Then the probability of exactly one fatality occurring during a remediation project is estimated based on the Poisson function as follows,

Probability of exactly one fatality, $f(x) = (e^{-u} * u^{x}) / x!$

where $x = 1$.

- The probability or risk of experiencing at least one fatality is then,

$$f(x>1) = 1 - f(0)$$

As discussed above, this risk of accident-related fatalities may be underestimated in this analysis since the accident frequencies are not specific to the hazardous waste remediation industry, and do not account for the potentially adverse affects of wearing PPE.

3.0 Results

Using the approximate manpower estimates prepared for the remedial alternatives evaluated in the FS, the methodology presented by Hoskin et al. (1994) and published fatal injury statistics (Hoskin et al., 1994; BLS, 1994 through 1999), the risk of worker fatalities during implementation of each remedy was calculated. The results of these worker risk estimates are presented in Table 1 and summarized in the table below. It should be noted that worker risks were not estimated for Alternatives 1 and 2 since these remedies are expected to involve a relatively insignificant amount of activity requiring extensive field labor or the use of heavy equipment.

Worker Risk Estimates

Remedial Alternative	Risk of at Least One Fatality
Alternative 3 Bank Stabilization	1.95×10^{-2}
Alternative 4 River-Wide Capping	3.79×10^{-1}
Alternative 5 River-Wide Dredging with Upland Confined Disposal	8.78×10^{-1}

References

Hoskin, A.F., J.P. Leigh, T.W. Planet. 1994. "Estimated Risk of Occupational Fatalities Associated with Hazardous Waste Site Remediation," *Risk Analysis*, Vol. 14, No. 6.

Leigh, J.P. and A.F. Hoskin. 1999. "Hazards for Nearby Residents and Cleanup Workers of Waste Sites," *Journal of Occupational and Environmental Medicine*, Volume 41, Number 5, May 1999, pp. 331-348.

U.S. Department of Labor, Bureau of Labor Statistics (BLS). 1994 through 1999. *Census of Fatal Occupational Injuries*.

U.S. Army. 1987. *Risk Analysis of the Disposal of Chemical Munitions at National and Regional Sites*. SAPEO-CDE-US-87008. August 1987.

Table

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TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
WORKER RISK ESTIMATES

REMEDIATION LABOR CATEGORY	ASSUMED OCCUPATION CLASS	OCCUPATION FATALITY RATE (death rate/person-yr)	REFERENCE	Alternative 3 Bank Stabilization			Alternative 4 River-Wide Capping			Alternative 5 River-Wide Dredging with Upland Confined Disposal		
				Estimated Hours	% Hours Distribution	Weighted Rate	Estimated Hours	% Hours Distribution	Weighted Rate	Estimated Hours	% Hours Distribution	Weighted Rate
Project Manager	Manager	3.20E-05	Leigh & Hoskin (1999)	9,216	5.41	1.73E-06	140,400	5.26	1.68E-06	325,350	2.69	8.62E-07
Field Engineer/Demolition Expert	Civil Engineer	3.28E-05	Hoskin et al (1994)	18,432	10.82	3.55E-06	140,400	5.26	1.73E-06	483,306	4.00	1.31E-06
Technicians / Laborers	Laborer	3.70E-04	BLS (1999)	65,485	38.45	1.42E-04	421,200	15.79	5.84E-05	3,078,000	25.47	9.42E-05
IQAT Members	Construction Inspector	8.90E-05	Leigh & Hoskin (1999)	18,432	10.82	9.63E-06	140,400	5.26	4.68E-06	108,000	0.89	7.95E-07
Field Supervisor / Foreman	Foreman. Const. Trade Super.	1.11E-04	BLS (1999)	12,272	7.20	8.00E-06	140,400	5.26	5.84E-06	756,000	6.26	6.94E-06
Equipment Operator	Dozer, Grader Operator	2.85E-04	BLS (1994 - 1997)	34,976	20.53	5.85E-05	561,600	21.05	6.00E-05	2,862,000	23.68	6.75E-05
Carpenter	Carpenter	7.40E-05	BLS (1999)	4,608	2.71	2.00E-06	0	0.00	0.00E+00	270,000	2.23	1.65E-06
Electrician	Electrician	1.26E-04	BLS (1999)	4,608	2.71	3.41E-06	0	0.00	0.00E+00	324,000	2.68	3.38E-06
Plumber	Plumber	1.31E-04	Hoskin et al. (1994)	2,304	1.35	1.77E-06	0	0.00	0.00E+00	432,000	3.57	4.68E-06
Specialized Operator	Operating engineer	1.68E-04	BLS (1994 - 1997)	0	0.00	0.00E+00	140,400	5.26	8.86E-06	0	0.00	0.00E+00
Water-Based Crew Member	Water transportation	5.85E-04	BLS (1995)	0	0.00	0.00E+00	982,800	36.84	2.16E-04	3,446,064	28.52	1.67E-04
Total Estimated Hours				170,333	100.00		2,667,600	100.00		12,084,720	100.00	
Weighted Death Rate / person-yr						**2.31E-04**			**3.57E-04**			**3.48E-04**
Total Estimated Time (person-years) (1)				85			1,334			6,042		
Mean No. of Fatalities (2)						**1.97E-02**			**4.76E-01**			**2.10E+00**
Risk of at least one fatality (3)						**1.95E-02**			**3.79E-01**			**8.78E-01**

NOTES:
1 The equivalent total labor requirement for the remedy based on a 40 hr work week, 50 weeks/yr
2. Mean number = (total estimate time) x (weighted death rate)
3 Risk estimate is the probability of at least one fatality occuring assuming on a Poisson probability distribution.

Appendix H

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Transportation Risks Associated With Importing Fill to the Site

Appendix H – Transportation Risks Associated with Importing Fill to the Site

1.0 Summary

The risk of a collision and the risk of a collision-related fatality or injury have been quantified in this analysis for off-site transport of Site-related materials for the three remedial alternatives listed below:

- Alternative 3 – Bank Stabilization at the Former Impoundments, Monitored Natural Attenuation, and Institutional Controls
- Alternative 4 – River-Wide Capping of Submerged Sediments, Bank Stabilization at the Former Impoundments, Institutional Controls, and Monitoring
- Alternative 5 – River-Wide Dredging of Submerged Sediments with Upland Confined Disposal, Bank Stabilization at the Former Impoundments, Institutional Controls, and Monitoring

The estimated number of collisions and collision-related fatalities and injuries is presented in Table 1 and summarized below. Estimates were not prepared for Alternatives 1 and 2 because no off-site transportation of materials is associated with either remedy.

Calculation of the risk of collisions and collision-related fatalities and injuries is presented below.

2.0 Collision Frequency

2.1 Calculation of Collision Frequency

The potential number of collisions over the length of the remedial activity involving trucks transporting Site-related materials on a particular route (the "designated route," A_s) is calculated by multiplying the vehicle-miles traveled (AVMT) for those trucks by the overall truck accident frequency on the designated route:

$$A_s = AVMT_s \times AF_t$$

where:

$AVMT_s$ = Vehicle-miles traveled on the designated route by trucks carrying Site-related materials (vehicle-miles/remedy period in years), and

AF_t = Overall truck accident frequency on the designated route (accidents/vehicle-miles).

The $AVMT_s$ is equal to the length of the designated route (D) multiplied by the number of trucks transporting Site-related materials on the designated route during the remedy period (N_s):

$$AVMT_s = D \times N_s$$

where:

D = Length of the designated route (miles/truck), and

N_s = Number of trucks transporting Site-related materials on the designated route (trucks/remedy period in years).

The overall truck accident frequency on the designated route (AF_t) is equal to the total number of truck accidents on the designated route (A_t) each year divided by the AVMT on the designated route by all trucks ($AVMT_t$):

$$AF_t = A_t / AVMT_t$$

where:

A_t = Number of overall truck accidents on the designated route (accidents/year); and

$AVMT_t$ = Overall truck AVMT (vehicle-miles/year).

The Site-specific data used to calculate the frequency of a collision by trucks transporting fill materials to the site during the respective remedy are described below.

2.2 Site-Specific Traffic Data

Length of the Designated Route (D)

The total length of the designated route from the source of fill to the Site for each respective remedy is:

- Alternative 3 – 10 miles,
- Alternative 4 – 15 miles, and
- Alternative 5 – 10 miles.

The route distances listed above are for one-way travel. The lengths of the designated routes are doubled in this analysis to account for round-trip travel.

Number of Trucks Transporting Fill on the Designated Route (N_s)

The number of trucks carrying fill on a designated route (N_s) to the Site for each respective alternative is estimated to be:

- Alternative 3 – 70,000 truck loads,
- Alternative 4 – 2,519,000 truck loads, and
- Alternative 5 – 4,640,000 truck loads.

Number of Overall Truck Accidents (A_t) and Annual Vehicle-Miles Traveled by Trucks on the Designated Route ($AVMT_{t,s}$)

The number of truck accidents and the truck vehicle-miles traveled along the designated routes are based on national statistics. National truck traffic data were obtained from U.S. Department of Transportation's (U.S. DOT's) *1997 National Transportation Statistics* book (US DOT, 1996). The number of truck accidents and the truck vehicle-miles traveled along the designated routes is presented in Table 2. As shown in the table, the overall truck accident frequency (AF_t) was calculated for each portion of the designated route for the years that the federal DOT provided truck accident and truck vehicle-mile data. The average accident frequency was then calculated for the years that data were provided by the federal DOT.

Estimated Number of Collisions During the Remedy Period Involving Trucks Transporting Site-related Materials

The calculation of the number of accidents estimated to occur during the remedy period (A_s) on the designated route associated with each of the remedial alternatives assessed in this analysis is shown in Table 2. The estimated number of accidents for each alternative is:

- Alternative 3 – 3 accidents,
- Alternative 4 – 176 accidents, and
- Alternative 5 – 217 accidents.

3.0 Frequency of Collision-Related Fatalities

The frequency of collision-related fatalities for trucks transporting Site-related materials, F_f, was derived using the equation shown in Table 3 and described below.

The potential number of fatalities estimated to occur during the remedy period involving trucks transporting Site-related materials is calculated by multiplying the estimated number of accidents each year involving trucks carrying Site-related materials by the probability of a fatality occurring during a truck accident:

$$F_f = A_s \ x \ P_f$$

where:

F_f = Number of fatalities involving trucks transporting Site-related materials (fatalities/remedy period in years);

A_s = Number of accidents involving trucks transporting Site-related materials (accidents/remedy period in years); and

P_f = Probability of a fatality resulting from a collision (unitless).

According to the U.S. DOT (1996), there are 644 fatalities for every 362,000 accidents involving a large truck. (The U.S. DOT (1996) defines a large truck as a truck having over 10,000 pounds gross vehicle weight rating, including single-unit trucks and truck tractors.) Therefore, the number of fatalities per truck accident (P_f) is approximately 0.00178, or about 2 fatalities for every 1,000 collisions. Thus, the likelihood of a collision-related fatality during transport of Site-related materials for the respective alternatives is as follows:

- Alternative 3 – 1 in 170 chance,
- Alternative 4 – 1 in 3 chance, and
- Alternative 5 – 1 in 3 chance.

4.0 Frequency of Collision-Related Injury

The frequency of collision-related injuries for trucks transporting Site-related materials, F_i, was derived using the equation shown in Table 4 and described below.

The potential number of injuries estimated to occur during the remedy period involving trucks transporting Site-related materials is calculated by multiplying the estimated number of accidents each year involving trucks transporting Site-related materials by the probability of an injury occurring during a truck accident:

$$F_i = A_s \ x \ P_i$$

where:

F_i = Number of injuries involving trucks transporting Site-related materials (injuries/remedy period in years);

A_s = Number of accidents involving trucks transporting Site-related materials (accidents/remedy period in years); and

P_i = Probability of an injury resulting from a collision (unitless).

According to the U.S. DOT (1996), there are 30,000 injuries for every 362,000 accidents involving a large truck. Therefore, the number of injuries per truck accident (P_i) is approximately 0.0829, or about 8 injuries for every 100 collisions. Thus, the estimated number of injuries during the remedy period for the respective alternative is as follows:

- Alternative 3 – less than 1 injury,
- Alternative 4 – 15 injuries, and
- Alternative 5 – 18 injuries.

References

Federal Emergency Management Agency (FEMA). 1993. *Handbook of Chemical Hazard Analysis Procedures.* NTIS PB93-158756.

U.S. Department of Transportation (U.S. DOT). 1996. Bureau of Transportation Statistics. *1997 National Transportation Statistics.* DOT-VNTSC-BTS-96-4. December 1996.

Tables

TABLE 1

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
SUMMARY OF ESTIMATED NUMBER OF COLLISIONS AND COLLISION-RELATED FATALITIES AND INJURIES ASSOCIATED WITH OFF-SITE TRANSPORT OF SITE-RELATED MATERIALS

	Alternative 3 **Bank Stabilization**	**Alternative 4** **River-Wide Capping**	**Alternative 5** **River-Wide Dredging with Upland Confined Disposal**
Estimate Number of Accidents	3.3	176	217
Estimated Number of Collision-Related Fatalities	0.0058	0.31	0.39
Estimated Likelihood of Collision-Related Fatalities	1 in 170 chance	1 in 3 chance	1 in 3 chance
Number of Estimated Collision-Related Injuries	0.27	15	18

TABLE 2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
CALCULATION OF THE NUMBER OF ACCIDENTS INVOLVING TRUCKS TRAVELING FROM THE SITE TO THE DISPOSAL AREA (ROUND TRIP)

	Alternative 3 - Bank Stabilization	Alternative 4 - River-wide Capping	Alternative 5 - River-wide Dredging with Upland Confined Disposal
A_s, Number of Accidents Involving Trucks Transporting Site-Related Materials (accidents/remedy period) $A_s = AVMT_S \times AF_t$	3.27	176.31	216.50
AF_t, Overall (Average) Truck Accident Frequency (accidents/vehicle-miles)	2.33e-06	2.33e-06	2.33e-06
Truck Accident Frequency Per Year (accidents/vehicle-miles) $AF_t = A_t/AVMT_t$			
1990	2.48e-06	2.48e-06	2.48e-06
1991	2.12e-06	2.12e-06	2.12e-06
1992	2.38e-06	2.38e-06	2.38e-06
1993	2.38e-06	2.38e-06	2.38e-06
1994	2.61e-06	2.61e-06	2.61e-06
1995	2.03e-06	2.03e-06	2.03e-06
A_t, Number of Truck Accidents Per Year (accidents/year) [USDOT 1996]			
1990	3.72e+05	3.72e+05	3.72e+05
1991	3.19e+05	3.19e+05	3.19e+05
1992	3.63e+05	3.63e+05	3.63e+05
1993	3.81e+05	3.81e+05	3.81e+05
1994	4.44e+05	4.44e+05	4.44e+05
1995	3.62e+05	3.62e+05	3.62e+05

TABLE 2

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
CALCULATION OF THE NUMBER OF ACCIDENTS INVOLVING TRUCKS TRAVELING FROM THE SITE TO THE DISPOSAL AREA (ROUND TRIP)

	Alternative 3 - Bank Stabilization	Alternative 4 - River-wide Capping	Alternative 5 - River-wide Dredging with Upland Confined Disposal
$AVMT_t$, Truck Vehicle Miles Traveled Per Year (vehicle-miles/year) [USDOT 1996]			
1990	1.50e+11	1.50e+11	1.50e+11
1991	1.51e+11	1.51e+11	1.51e+11
1992	1.53e+11	1.53e+11	1.53e+11
1993	1.60e+11	1.60e+11	1.60e+11
1994	1.70e+11	1.70e+11	1.70e+11
1995	1.78e+11	1.78e+11	1.78e+11
$AVMT_s$, Total vehicle miles traveled by trucks transporting Site-related materials (vehicle-miles/Remedy period) $AVMT_s = D \times N_s$	1,400,000	75,570,000	92,800,000
N_s, Number of Trucks Carrying Site-related material on the Designated Route (trucks/remedy period)	70,000	2,519,000	4,640,000
D, Length of Designated Route (miles/truck) Round Trip)	20	30	20

TABLE 3

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
ESTIMATED NUMBER OF COLLISION-RELATED FATALITIES

Parameter	Alternative 3 - Bank Stabilization	Alternative 4 - River-wide Capping	Alternative 5 - River-wide Dredging with Upland Confined Disposal	Reference
F_f, Number of fatalities involving trucks carrying site-related material from the Site to a disposal area (fatalities/remedy period)	0.006	0.314	0.385	Calculated $F_f = A_s \times P_f$
A_s, Number of accidents involving trucks carrying Site-related material from the Site to a disposal area (accidents/remedy period) (Round Trip)	3.27	176.31	216.50	Calculated See Table 2
P_f, Probability of a fatality resulting from a collision (fatality/accident)	0.00178	0.00178	0.00178	U.S. DOT, 1996

TABLE 4

ALLIED PAPER, INC./PORTAGE CREEK/KALAMAZOO RIVER SUPERFUND SITE

FEASIBILITY STUDY REPORT
ESTIMATED NUMBER OF COLLISION-RELATED INJURIES

Parameter	Alternative 3 - Bank Stabilization	Alternative 4 - River-wide Capping	Alternative 5 - River-wide Dredging with Upland Confined Disposal	Reference
F_I, Number of injuries involving trucks carrying Site-related material from the Site to a disposal area (fatalities/remedy period) (Round Trip)	0.27	14.61	17.94	Calculated $F_I = A_s \times P_I$
A_s, Number of accidents involving trucks carrying Site-related material from the Site to a disposal area (accidents/remedy period)	3.27	176.31	216.50	Calculated See Table 2
P_I, Probability of an injury resulting from a collision (injury/accident)	0.0829	0.0829	0.0829	U.S. DOT, 1996